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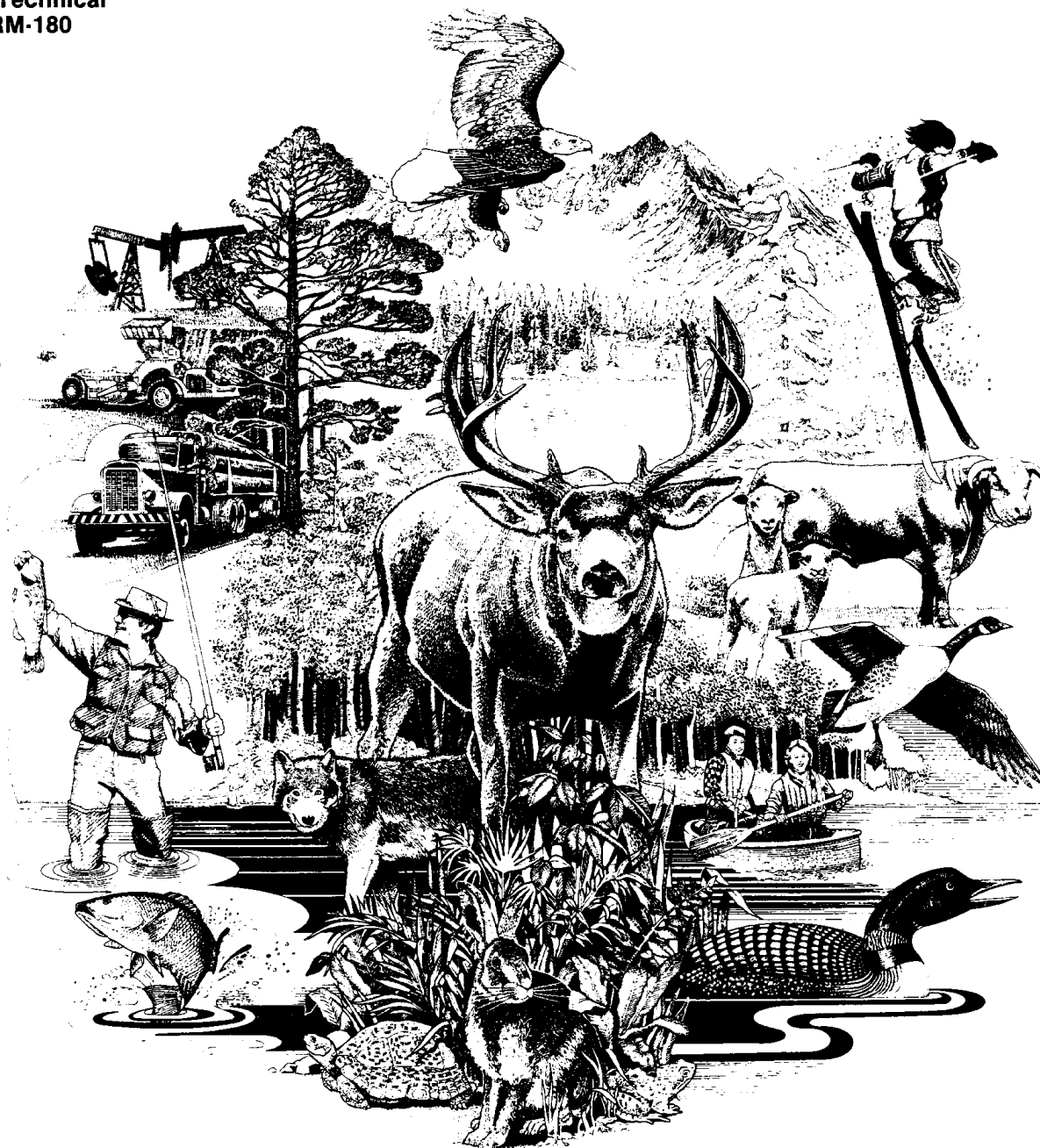
General Technical
Report RM-180



An Analysis of the Range Forage Situation in the United States: 1989-2040

A Technical Document Supporting the
1989 USDA Forest Service RPA Assessment

Linda A. Joyce



Preface

The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA), P.L. 93-378, 88 Stat. 476, as amended, directed the Secretary of Agriculture to prepare a Renewable Resources Assessment by December 31, 1975, with an update in 1979 and each 10th year thereafter. This Assessment is to include "an analysis of present and anticipated uses, demand for, and supply of the renewable resources of forest, range, and other associated lands with consideration of the international resource situation, and an emphasis of pertinent supply, demand and price relationship trends" (Sec. 3.(a)).

The 1989 RPA Assessment is the third prepared in response to the RPA legislation. It is composed of 12 documents, including this one. The summary Assessment document presents an overview of analyses of the present situation and the outlook for the land base, outdoor recreation and wilderness, wildlife and fish, forest-range grazing, minerals, timber, and water. Complete analyses for each of these resources are contained in seven

supporting technical documents. There are also technical documents presenting information on interactions among the various resources, the basic assumptions for the Assessment, a description of Forest Service programs, and the evolving use and management of the Nation's forests, grasslands, croplands, and related resources.

The Forest Service has been carrying out resource analyses in the United States for over a century. Congressional interest was first expressed in the Appropriations Act of August 15, 1876, which provided \$2,000 for the employment of an expert to study and report on forest conditions. Between that time and 1974, Forest Service analysts prepared a number of assessments of the timber resource situation intermittently in response to emerging issues and perceived needs for better resource information. The 1974 RPA legislation established a periodic reporting requirement and broadened the resource coverage from timber to all renewable resources from forest and rangelands.

An Analysis of the Range Forage Situation in the United States: 1989-2040

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Acknowledgments

A report of this magnitude is necessarily the result of many people's efforts. The economic analysis of future forage demand was made by Dr. C. Kerry Gee, retired Economic Research Service, USDA, and Dr. Al Madsen, Colorado State University, using livestock projections made by William Quinby, Economic Research Service, USDA. The cooperation of Robert Williamson and the Range Management Staff, USDA Forest Service, facilitated the public forage supply analyses. In particular, Edward Schlatterer helped access data and source material, collaborated in writing chapter 7, and reviewed all chapters. Edward Frandsen determined current range forage values. These latter analyses benefited from research by Terry Crawford, Economic Research Service, USDA. Amalgamating inventory information was facilitated by the cooperation of the regional Range staff directors of the USDA Forest Service; Willie Peterson, Bureau of Land Management; and David Chalk, Thomas Shiflet, Don Pendleton, William Maetzold, Soil Conservation Service. The evolution of written material was helped greatly by the reviews of Dr. Thomas Quigley, Dr. Fee Busby, Dr. Bill Krueger, Dr. Arden Pope, Dr. Henry Pearson, Dr. Earl Aldon, Dr. Gale Wolters, and Ron Michaeli. A special thanks is extended to Terri Tucker Schulz who managed the assessment data and contributed to the discussion of riparian management. Many thanks go to Karen Omeg, and Marj Swanson for typing and retyping tables. Coordination of assessment activities was greatly helped by the experience of the RPA staff, Forest Service, most particularly, Adrian Haught and Dave Darr. Charged with similar objectives of assessing natural resources, the collegiality of Thomas Hoekstra, John Hof, and Curt Flather made life seem endlessly creative when new research ideas were cast up and carried the day when deadlines were to be met.

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CHAPTER 1: THE RANGE RESOURCE

INTRODUCTION

Range and range resources are many things to many people. In the broad view, range is a type of land, a kind of vegetation, and a way of management (Range Inventory Standardization Committee 1983, U.S. Senate 1936). Previous studies or assessments on the Nation's range resources have had broad objectives, such as the Forest-Range Environmental Study (USDA Forest Service 1972), or the 1980 Assessment (USDA Forest Service 1980), or have focused on specific issues, such as range condition (U.S. General Accounting Office 1988).

The mandate for the present assessment is the Resource Planning Act (RPA) of 1974 which directs the Forest Service (FS) to prepare an Assessment of the Nation's renewable resources every 10 years. As directed by this legislation, the assessment shall include but not be limited to "an analysis of present and anticipated uses, demand for, and supply of the renewable resources, with consideration of the international resource situation, and an emphasis of pertinent supply and demand and price relationship trends".² The present report analyzes the range resource from a national perspective, includes public and private lands, and uses information collected by other public agencies as well as the Forest Service.

Chapter 1 describes the current status of the range resource, the multiple outputs currently produced from range vegetation, the land area and productivity of range vegetation. The factors affecting supply and demand of range outputs (Chapters 2 and 3) are used to develop a projection of future supply and demand (Chapter 4). The social, economic, and environmental implications of this future scenario are reviewed in Chapter 5, opportunities for and obstacles to managing the range resource are discussed in Chapter 6, and the implications to all Forest Service programs, including the National Forest System (NFS) renewable resource program, Research, and State and private forestry programs are discussed in Chapter 7. Terms used in this report are defined in the Glossary (Appendix D). Scientific and common names for all plants mentioned in this report are given in Appendix A. Scientific and common names for all animals mentioned in this report are given in Flather and Hoekstra (in press).

Four Assessment regions are used to present resource data: the Northern (NO), Southern (SO), Pacific Coast (PC), and Rocky Mountain (RM). For the present report, a finer delineation of the western regions is used, where possible (fig. 1). The Pacific Coast region is broken into the Pacific North (PN) and California (CA) regions. The Rocky Mountain is broken into the Northern Rocky (NR) Mountain and the Southwest (SW) regions. Alaska and Hawaii are treated separately.

RANGE AND RANGE RESOURCES

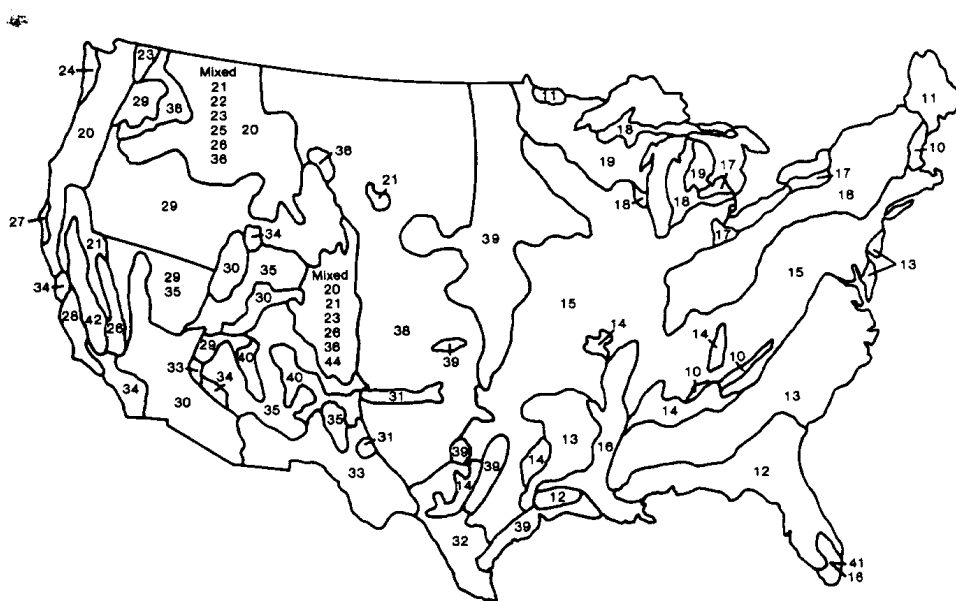
Range vegetation is defined as grasses, grass-like plants, forbs, and shrubs. This definition includes introduced species that are managed like native plants. When the vegetation (climax or natural potential) is dominated by range vegetation, the land is referred to as rangeland. Whereas rangelands predominate in western United States as natural grasslands, shrublands, savannas, deserts, tundra, alpine, coastal marshes, and wet meadows, rangeland also occurs as tallgrass prairie, marshes, and wet meadows in eastern United States. Riparian ecosystems, and plant communities dominated by introduced species are also considered rangelands. Range vegetation is most commonly associated with grasslands and shrublands, but forest lands also support an understory of grasses, grass-like plants, forbs, and shrubs. Range vegetation forms the basic building block in the production of multiple resources from forest and rangelands.

In this document, the diversity of vegetation on forest and rangeland is described using the 34 ecosystems of the Forest and Range Environmental System (FRES) (fig. 2, table 1). This classification system is based on broad groupings of the Küchler (1964) communities and forest and woodland types from the FS survey (USDA Forest Service 1967). The mountain meadow vegetation type, an important forage source, was added to Küchler's system and this amended classification was renamed *Potential Natural Communities* (PNC) to mark the distinction from Küchler's classification (Mitchell and Joyce 1986). The PNC represents the biotic community that would become established if all successional sequences proceeded without interference by humans under the

²Forest and Rangeland Renewable Resources Planning Act. Act of Aug. 17, 1974. 88 Stat. 476, as amended; 16 U.S.C. 1600-1614.



Figure 1.—Assessment regions of the United States.



Source: Garrison and others.

Figure 2.—FRES ecosystems of the United States (see table 1 for explanation of numerals).

present environmental conditions (Range Inventory Standardization Committee 1983). A brief description of each FRES ecosystem is given in Appendix B.

Climatic, geological, and elevational differences across the United States result in the diversity of ecosystems from spruce-fir in Maine, to wet grasslands in Florida, and to chaparral mountain shrub ecosystems in California (fig.

2). For areas in the western United States, the environmental heterogeneity of the landscape induces a mixture of ecosystems within a short geographic distance, necessitating a listing of these types, rather than a finer delineation in figure 2. The diversity of vegetation across the nation's landscape gives an indication of the diversity of renewable resources from forest and rangelands.

Table 1.—Explanation of FRES ecosystems shown in figure 1.

Number	Ecosystem	Number	Ecosystem
10	White-red-jack pine	27	Redwood
11	Spruce-fir	28	Western hardwoods
12	Longleaf-slash pine	29	Sagebrush
13	Loblolly-shortleaf pine	30	Desert shrub
14	Oak-pine	31	Shinnery
15	Oak-hickory	32	Texas savanna
16	Oak-gum-cypress	33	Southwestern shrubsteppe
17	Elm-ash-cottonwood	34	Chaparral-mountain shrub
18	Maple-beech-birch	35	Pinyon-juniper
19	Aspen-birch	36	Mountain grasslands
20	Douglas-fir	37	Mountain meadows ¹
21	Ponderosa pine	38	Plains grasslands
22	Western white pine	39	Prairie
23	Fir-spruce	40	Desert grasslands
24	Hemlock-Sitka spruce	41	Wet grasslands
25	Larch	42	Annual grasslands
26	Lodgepole pine	43	Alpine

¹Not mapped.

Source: Garrison et al. 1977.

MULTIPLE RESOURCE PRODUCTION ON FOREST AND RANGELANDS

The many products flowing from management of the Nation's forest and rangelands are not independent of nor are they produced in constant relation to each other. This relation can best be described as joint production, wherein multiple inputs are combined to produce multiple outputs. The management of these multiple inputs to produce these multiple outputs is range management. Range management includes:

- determining suitability of vegetation for multiple resource uses;
- designing and implementing range vegetation improvement practices;
- understanding social and economic effects of management alternatives;
- controlling range insects;
- determining wildlife, recreational, wild horse and burro, and livestock carrying capacities;
- protecting soil stability;
- reclaiming disturbed areas;
- designing and controlling livestock management systems;
- managing and controlling undesirable range vegetation;
- coordinating management activities with other land and resource managers;
- maintaining environmental quality including soil, water, and air (USDA Forest Service 1987c).

Forage is browse and herbage which is available and may provide food for grazing animals or be harvested for feed (Range Inventory Standardization Committee 1983). Range is commonly perceived as producing only forage for livestock. Although livestock grazing is an important use of grazinglands, both forest and rangeland,

livestock grazing is not the only use and in some parts of the world is not the most important or best economic or social use of rangelands (Busby 1987). Range outputs and range management are broader issues than domestic livestock. The diversity of outputs from range ecosystems includes forage for both domestic and wild herbivores, firewood and specialty wood products, seed sources for agricultural or reclamation or landscaping purposes, minerals, water quality and quantity, air quality, open space, threatened and endangered plants and animals, genetic material, recreational use, plant and animal diversity, human community stability, and scenic quality. All plant and animal species that depend on rangeland or range vegetation are dependent on range management and must be considered as a product or output of range management. The production of timber and range vegetation, or wild and domestic herbivores, are interdependent in that the management for one output affects the yield of the other. Thus, the management of the Nation's forests and rangelands must recognize tradeoffs or enhancements across resource production opportunities (Hof and Baltic 1988).

The importance, and ultimately the use, of rangelands is often determined by cultural factors in society (Box 1988). Hunter-gather societies and pastoral economies value food production from rangelands. Urban societies value rangelands and forests for clean water production and recreation opportunities. Increased human densities in developed countries raise the question of waste disposal on rangelands while placing a higher value on wilderness for recreation. To reach and maintain these desired objectives while protecting fragile soils and watersheds, the managers of range vegetation must apply knowledge, skills, and techniques based on ecological principles. The joint products that result from range management are important outputs that need to be recognized as goals, objectives, benefits, and uses of the range

resource. A review of some of the current outputs from rangelands and forests follows.

Agricultural, Reclamation, and Landscaping Uses of Range Plants

Interest in the harvest and cultivation of native plants is increasing as society seeks less water-consuming or low maintenance plants for agriculture, land reclamation, and landscaping (Aldon et al. 1987, Goodin and Northington 1985, Hinman 1984, Patton et al. 1986). Range plants are harvested or cultivated for oil, rubber, fruits, vegetables, nuts, grains, medicines, ornamentals, firewood, and specialty wood products (table 2). Cacti are utilized for fruit, green vegetables, forage, fodder, gums for adhesives and thickening foods, strong fibers and ornamentals (Russell and Felker 1987, Vietmeyer

1986). The harvest of prickly pear cactus fruit in Mexico is more than twice the world's harvest of apricot, papaya, strawberries, or avocados (Vietmeyer 1986). Seed from jojoba, a southwestern shrub, yields a valuable lubricating oil (fig. 3). In 1986, the combined harvest of jojoba seed for the United States, Mexico, and Israel was 820 metric tons; a substantial increase over the 12 metric tons harvested in 1976 (Gillis 1988). Guayule, another southwestern shrub, has supplied significant quantities of rubber during previous world wars (Foster and Moore 1987); other plants such as buffalo gourd, gopher plant, and gumweed offer possible sources for oil or rubber (Hinman 1984, Hoffman and McLaughlin 1986, Johnson and Hinman 1980, Patton et al. 1986). Increasing numbers of urban centers in the western United States encourage the use of xeric landscaping to reduce water use. Water use efficiency is much greater for some native plants than plants traditionally used

Table 2.—Resource outputs from range ecosystems.

FRES ecosystem	Plant value	Herbage production (pounds per acre)	Large herbivores	Threatened and endangered animal species
Sagebrush	Forage, browse	0–2,000	Deer, pronghorn, wild horses and burros, sheep, cattle	Utah prairie dog
Desert shrub	Mesquite-fuelwood, charcoal, forage, browse, ornamental cactus, rubber, oil	0–1,000	Deer, pronghorn, bighorn sheep, wild horses and burros, sheep, goats, cattle	Masked bobwhite Sonoran pronghorn
Shinnery	Forage, browse	500–2,000	Deer, cattle	
Texas savanna	Mesquite-fuelwood, charcoal, forage, browse, rubber	0–3,000	Deer, cattle, sheep, goats	Jaguarundi Ocelot Northern aplomado falcon
Chaparral-mountain shrub	Acorns, forage, browse	0–2,000	Deer, wild horses and burros, goats	California condor San Joaquin kit fox
Pinyon-juniper	Christmas trees, fuelwood, pine nuts, fence posts, chips, forage, browse	0–800	Deer, elk, cattle	Thick-billed parrot
Mountain grasslands	Forage	1,000–2,000	Deer, elk, pronghorn, cattle, sheep	
Mountain meadows	Forage	0–4,000	Deer, elk, moose, cattle	
Plains grasslands	Wildflowers, landscaping, forage	0–2,000	Deer, pronghorn, cattle, sheep	Black-footed ferret Northern swift fox
Prairie	Wildflowers, landscaping, forage	1,500–6,000	Deer, pronghorn, cattle	Attwater's prairie chicken Northern swift fox Red wolf
Desert grasslands	Ornamental cactus, landscaping, forage	0–1,000	Pronghorn, deer, cattle, sheep	Masked bobwhite
Wet grasslands	Forage	0–12,000	Deer, cattle	Everglades kite Whooping crane Attwater's prairie chicken
Annual grasslands	Forage	0–4,400	Deer, wild horses and burros, cattle	San Joaquin kit fox Giant kangaroo rat
Alpine	Forage	0–1,200	Deer, elk, bighorn sheep, sheep	Grizzly bear

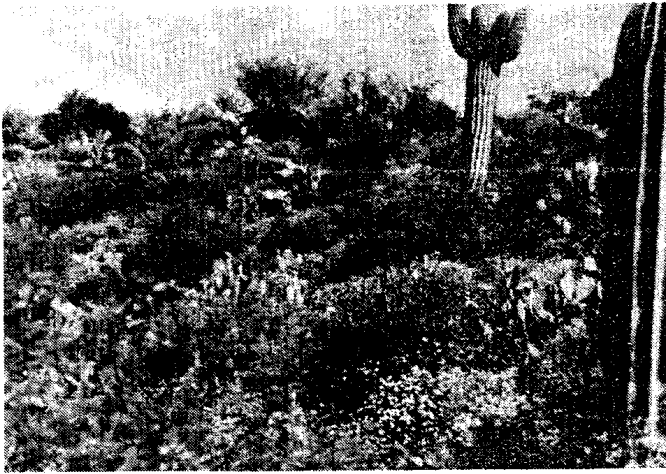


Figure 3.—Jojoba growing in association with saguro and cactus on Southwestern rangelands.

in urban landscaping (Front Range Xeriscape Task Force [n.d.]). Ecosystems particularly valuable for their landscaping resources are the prairie, plains and desert grassland ecosystems (table 2).

Initially, native seed sources or plants had been difficult to obtain because so little commercial work with arid species had been done. Mined land reclamation research has increased the availability of seed and plant sources. Government conservation programs that encourage the planting of cropland into native range also increase the demand for native plant seeds (Hijar 1988). Commercial nurseries offer an increasing number of native grasses, forbs, shrubs, and trees capable of withstanding long periods of dry weather (Diekelmann et al. 1986, Wallace et al. 1986).

Forage for Wild and Domestic Herbivores

Herbivores, animals that feed on plants, include wild-life such as elk, deer, and antelope, and livestock such as sheep, horses, goats, and cattle. Nearly all forest and rangeland ecosystems provide forage for wild and domestic herbivores. Forage production varies from less than 200 lbs/acre in dense forest stands (table 3) to greater than 2,000 lbs/acre in many grassland ecosystems (table 2). Greater numbers and more diversity in wild and domestic herbivores are found in ecosystems that provide greater amounts of forage and browse.

At least part of the feed mix for domestic horses, sheep, cattle, and goats and all of the feed mix for wild herbivores is forage produced on pasture, range, or forest land. Grazed roughages are forage harvested by grazing or browsing forest, rangeland, or pasture whereas harvested forages are mechanically harvested from pasture, haylands, or croplands seeded to forage crops. Harvested forages are important in providing feed for livestock during winter when little grazed roughages are available, or when forage is not readily accessible, such as for recreational horses in suburban areas. Harvested forages and stored crops are also used by wildlife as a source of winter feed (Schneidmiller 1988).

While the exact forage demand will vary by type and age of animal, population estimates of wild and domestic herbivores can be viewed as an indication of forage demand. The total number of cattle and calves for dairy and beef in 1985 was 105 million. Sheep numbers were 8.4 million and goats were about 1.6 million. The 1982 Census of Agriculture (USDC Bureau of Census 1984) reported approximately 2 million work horses on farms in the United States. Horses are increasingly becoming a recreational animal. Peat et al. (1987) estimated 5 million horses, predominately recreational stock, and the

Table 3.—Resource outputs from western forest ecosystems.

FRES ecosystem	Plant value	Herbage production (pounds per acre)	Large herbivores	Threatened and endangered animal species
Douglas-fir	Timber, forage, browse	50–1,400	Elk, deer, moose, sheep, cattle	Gray wolf Woodland caribou
Ponderosa pine	Timber-framing, millwork, forage, browse	50–1,200	Deer, elk, cattle	New Mexico ridge-nosed rattlesnake
Fir-spruce	Timber	100–900	Elk, deer, moose, mountain goats, bighorn sheep, cattle	Woodland caribou Grizzly bear
Hemlock-Sitka spruce	Timber	0–400	Elk, deer, moose	Columbian white-tailed deer
Western white pine	Timber	0–400	Elk, deer	
Larch	Timber	0–3,000	Elk, deer, moose, cattle	Woodland caribou
Lodgepole pine	Timber, forage, browse	40–2,300	Elk, deer, moose	
Redwood	Timber		Elk, deer	
Western hardwoods	Timber-paper, landscaping	1,400–2,000 500–4,000 (Aspen)	Deer, elk, cattle, sheep	California condor Columbian white-tailed deer

1985 United Nations Production yearbook (Food and Agriculture Organization 1986) reported 10.6 million horses in the United States. Numbers of white-tailed and mule deer are estimated to be over 16 million, pronghorn antelope over 700 thousand, and elk over 460 thousand (Council for Agricultural Science and Technology 1986). Smaller numbers of moose, bison, wild sheep, and mountain goats are also found in the United States (Flather and Hoekstra in press).

Demand for grazed roughages exists in every region of the United States (fig. 4). Large numbers of wild and domestic herbivores are found in the SO, the NO and the NR region. Deer and cattle are the most numerous herbivores in these regions. The NR region has the largest number of sheep, and the SO region, primarily Texas, has large numbers of goats.

Threatened and Endangered Plant and Animal Species

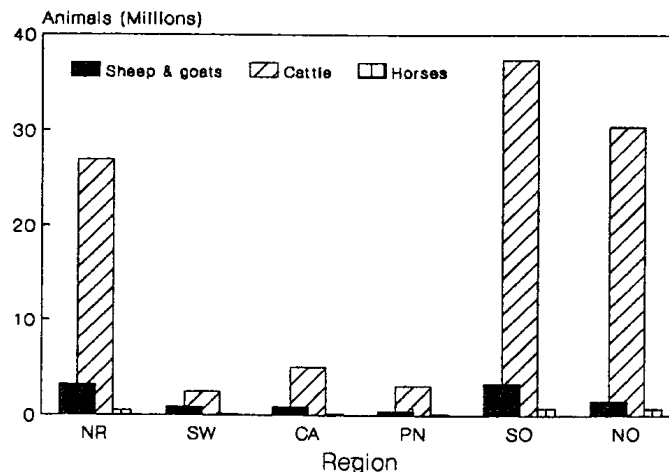
About 25,000 species, subspecies, and varieties of plants are native to the United States. The Center for Plant Conservation estimates that 680 of these plant species will be extinct in the United States by the year 2000 (Center for Plant Conservation 1988). Under the Endangered Species Act of 1973, federal agencies must ensure that their management actions will not jeopardize the existence of a threatened or endangered plant or animal species. As of July 1988, 185 plant species officially were classified as threatened (147) or endangered (38) (Appendix C). Threatened and endangered animal species can be found on most forest and rangeland ecosystems (tables 2, 3, and 4).

Although grazing pressure has been a concern, 25 species of the last 28 plant species officially listed as threatened or endangered were recognized because of increased human disturbance, either trampling, collecting, off-road vehicle use, road construction, quarrying, or deforestation. The most significant threat to the future existence of plants such as endangered cacti (fig. 5), however, is amateur and commercial collecting (Wright Fishhook Cactus Recovery Committee 1985). Recovery plans for restoring endangered or threatened plants had been approved for 70 plants as of July 1988 (USDI Fish and Wildlife Service 1988).

Wildlife

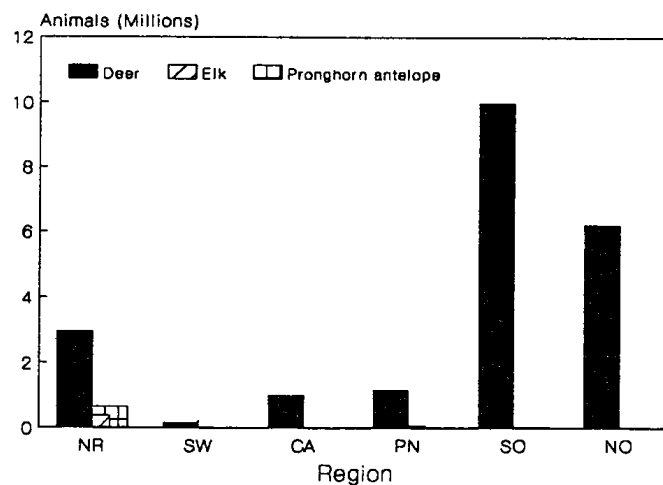
Wildlife and fish contribute to the functioning of ecosystems in roles such as pollination, seed dispersal and germination, nutrient cycling, and herbivory (Flather and Hoekstra in press). During some part of the year, rangeland ecosystems are associated with 84% and 74%, respectively, of the total number of mammal and avian species found in the United States (Flather and Hoekstra in press). Familiar rangeland species include big game such as pronghorn antelope, small game such as jackrabbit and sage grouse, nongame such as horned lark. Species mobility, public ownership, and state and

(a) Sheep, goats, cattle, and horses



Source: cattle and sheep: USDA, (1987); horses and goats: USDC, Census of Agriculture (1983)

(b) Deer, elk, and pronghorn antelope



Source: Council for Agricultural Sciences and Technology (1986)

Figure 4.—Number of large herbivores by assessment regions.

federal authority for management contribute to the complexity of wildlife and fish management and this complexity increases the importance of cooperation among the public and the managing agencies (Flather and Hoekstra in press).

Forest and rangelands provide food, cover, and water for wildlife (tables 2, 3, and 4) and changes either in the quantity or quality of habitat affect wildlife populations. Wildlife, if associated with specific habitats, are sensitive to changes in those ecosystems, as seen in the declining numbers of the long-billed curlew and the

Table 4.—Resource outputs from eastern forest ecosystems.

FRES ecosystem	Plant value	Herbage production (pounds per acre)	Large herbivores	Threatened and endangered animal species
White-red-jack pine	Timber	0-400	Deer, moose	Eastern timber wolf Kirtland's warbler
Spruce-fir	Timber	0-800	Deer, moose	Eastern timber wolf Woodland caribou
Maple-beech-birch	Timber	0-800	Deer, moose	Eastern timber wolf
Aspen-birch	Timber	0-400	Deer, moose, cattle	Eastern timber wolf
Oak-pine	Timber, acorns	50-500	Deer, cattle	Eastern cougar
Oak-hickory	Timber, acorns	200-3,000	Cattle, deer	Red wolf Northern flying squirrel
Loblolly-shortleaf pine	Timber, forage, browse	0-1,800	Deer, cattle	Red-cockaded woodpecker
Longleaf-slash pine	Pulp, paper, forage, browse	120-2,600	Deer, cattle	Red-cockaded woodpecker Florida panther
Oak-gum-cypress	Acorns, timber, forage, browse	0-2,000	Deer	Key deer Ivory-billed woodpecker Bachman's warbler Red wolf
Elm-ash-cottonwood	Forage	0-800	Deer, cattle	Eastern timber wolf

reduced area of shortgrass prairie (USDI Fish and Wildlife Service 1982). Lakes and ponds scattered across rangelands, especially in the Great Plains, are important nesting and wintering areas for waterfowl, and intensification of land use, either by grazing or agriculture, can degrade these waterfowl habitats. Two critical issues with respect to wildlife habitat on rangelands include the reduction of area and fragmentation of grassland habitats in the East, and the degradation of riparian habitats in the arid West (Flather and Hoekstra in press).

Wild Horses and Burros

The passage of the Wild Free-Roaming Horses and Burros Act of 1971 delegated authority and responsibility to the Secretaries of Interior and Agriculture for the protection, management, and control of wild free-roaming horses and burros on lands administered by the Bureau of Land Management (BLM) and the Forest Service. Only those public lands are considered in this Act. Wild horses and burros can be found in the many western ecosystems (table 2). Although the greatest number occurs in Nevada, wild horses are also found in California, Colorado, Idaho, Montana, New Mexico, Oregon, Utah, and Wyoming. The largest numbers of feral burros occur in Nevada, California, Utah, and Arizona but they are also found in Idaho, New Mexico, and Oregon. Current estimates indicate that the appropriate management levels for FS and BLM-administered lands is under 28,300 wild horses and 3,500 burros. In 1988, over 39,000 feral horses and 5,000 burros were found on FS and BLM-administered lands (USDA Forest Service and USDI Bureau of Land Management 1989). Since

1972, 81,000 animals have been placed through the federal adoption program.

Exotic Animals

The importation of exotic animals, either purposely or accidentally, has a long history in the United States. Some introductions, such as the ring-necked pheasant and the chukar, are considered beneficial, whereas other introductions, such as the Norway rat, are considered detrimental. Since the early 1900s, the number and type



Figure 5.—San Raphael cactus (*Pediocactus despainii*), an endangered cacti, is found in Utah (photo courtesy of Dr.—Kenneth Hell, San Juan College).

of exotic herbivores have continually increased (Doughty 1983). Whereas ranchers originally introduced these animals as attractions, big game ranching has expanded into meat production, live animal sales to zoos or other game ranches, hunting opportunities, and recreational experiences for tourists such as viewing parks. Numbers of some species are now greater in the United States than in their country of origin, and interest in breeding these animals on ranches for zoos has increased (U.S. Congress, Office of Technology Assessment 1986a). Exotic animals are found in large numbers in Texas, but also occur in other states. Exotic animals have been harvested in 22 states (Temple 1982 as cited by White 1987) and membership of the Exotic Wildlife Association in 1985 was 192 members in 18 states (Nicholl 1985, personal communication cited in White 1987).

Water

All range and forest lands function as watersheds that drain into either aquifers or aboveground water storage for agricultural, industrial, municipal, recreational, and navigational uses. High-elevation watersheds are primary water-producing areas in both eastern and western United States. Low-elevation watersheds, used primarily for livestock grazing, contribute little to water quantity, but are important in terms of water quality (Tiedemann et al. 1987). Water management policy has traditionally assumed that the supply of water is a fixed constant (Conservation Foundation 1987). Climate, one of the natural determinants of water quantity, is a dynamic process. Improved analyses of the historical variabilities in climate and the recently recognized potential impacts of human societies on future climate are causing a new awareness of the dynamics of water production (Waggoner 1988). The future management of forest and rangelands will increasingly focus on water production, storage, and water quality (Dixon 1983, Guldin in press, Smith et al. 1987, U.S. Congress, Office of Technology Assessment 1983).

Riparian zones, significant to wild and domestic herbivores, are also important in maintaining water quality, the fisheries resource, and water-oriented recreation such as fishing, kayaking, white-water rafting, or boating (Flather and Hoekstra in press, Guldin in press, U.S. Congress, Office of Technology Assessment 1983). Riparian habitats are extremely productive systems with interchanges of energy, nutrients, and biotic material between the aquatic systems on their inner boundary and the upland range systems on their outer boundary (Kauffman and Krueger 1984). Riparian habitat deteriorates under overgrazing and may be lost when the land is converted to agricultural use, or the stream is channelized for flood control or is flooded for water storage. Where water development changes the flow velocity or periodicity, riparian zones may increase (Skinner 1986). Vegetation management within the riparian zone requires the consideration of the desired use of the area (Skovlin 1984).

Recreation and Scenery

Recreational opportunities on rangelands include non-motorized recreation such as hiking, horseback riding, picnicking, and skiing, and motorized recreation such as snowmobiling and use of off-road vehicles. Increasing demand for outdoor recreation places pressure on range and forest ecosystems to supply high quality recreational experiences. The long-term protection of recreation resources and open space is one of the high-priority issues facing state recreation agencies (Cordell in press). Demand for recreation is greatest near population centers. Ranching operations are important in maintaining open space in California (Huntsinger 1988). Improved coordination among public agencies, private groups, and industry is seen as a way to more efficiently provide future recreational experiences, facilities, and services on federal and private lands (Cordell in press).

The demand for horseback riding, a significant recreational use on NFS lands, is projected to almost double by 2040 (Cordell in press). Horse-riding activities are associated with private individuals and their own horses, with large groups from lodges adjacent to NFS lands, and with hunting parties led by outfitters (fig. 6). In terms of grazing use, the number of recreational stock is small compared with permitted livestock. Nonetheless, these recreational stock numbers offer some insight into the significance of this form of recreation. In 1986, over 45,000 Animal Unit Months (AUMs) of free recreational stock use were estimated to have occurred on NFS lands across the western United States (USDA Forest Service 1987b). Over 100,000 horses and burros were involved in this use.

Recreational opportunities on private lands have been developed to varying degrees across the United States. The first organized effort to capture additional income from Texas rangelands occurred in 1941 with the development of the Edwards Plateau Game and Wildlife Management Association (Berger 1973). Since then, the leasing of lands for recreational purposes such as hunting has grown, particularly in Texas (Pope and Stoll 1985, Pope et al. 1984a). Other opportunities developing in the private sector on ranches include hunting, fishing, swimming, horseback riding, hiking, camping, cross-country skiing, snowmobiling, photography, historical and geological tours, and bed and breakfast operations with the opportunity to participate in the working of the ranch (USDA Soil Conservation Service 1987c, Wyoming Farm Bureau 1987). Access to water for recreational fishing or boating is also producing income for private ranches.

Clearly the provision of recreation use in an area and how recreationists perceive their experience is influenced by the management of all range resources. Recreation use can impact the vegetation in a number of ways, such as harvesting of plants, trampling, erosive damage to hillsides, or braiding of roads and trails (Andrews and Nowak 1980, President's Commission on American Outdoors 1986). The degree of impact varies with the kind and intensity of recreational use and with environmental factors such as soils, and topography (Payne et al.

1983, Summer 1986). Many range ecosystems provide recreation along with grazing or timber outputs. A majority of recreationists interviewed in the Pacific Northwest indicated that their use of recreational areas would be altered if management intensity increased or became more apparent (Sanderson et al. 1986). The management of range and forest lands for multiple outputs will require a recognition of the type and quality of recreational experience desired, in combination with the production of other resources.

Minerals

Much of the western United States lies over deposits of valuable minerals, including coal and oil, metallic minerals such as lead and copper, precious metals and gems, and common building materials such as sand and gravel. Extracting these minerals is a major component of national, state and local economies. The western states of Texas, Oklahoma, California, New Mexico, Wyoming, together with Louisiana and West Virginia contributed more than 75% of the \$188 billion in value added by mining in 1982 (USDA Forest Service RPA Staff in press). Future projections suggest increased domestic production of metallic minerals and increased exploration for and production of domestic energy sources (USDA Forest Service RPA Staff in press). Extensive areas in western United States have been revegetated following mining (fig. 7) and measures will have to be taken to ensure that future mineral extraction is compatible with other uses and that environmental quality is maintained (USDA Forest Service RPA Staff in press).

FOREST AND RANGELAND

Ownership

The Nation's forest and rangeland base is managed by both federal and nonfederal ownerships. Private individuals and state and local governments comprise the nonfederal ownerships, and manage 67% of the total forest and rangeland base. The remaining 33% is under federal management (Bones in press). When rangeland alone is considered, about 64% is in nonfederal ownership. For forest land, nearly 71% is in nonfederal ownership. Land ownership patterns of forest and rangeland vary by region (table 5). Large federal holdings are found in many western states and federal statutes such as the Multiple-Use Sustained Yield Act of 1960, the Wilderness Act of 1964, the National Environmental Policy Act of 1969, the Wild Free-roaming Horse and Burro Act of 1971, the Federal Land Policy and Management Act of 1976, and the National Forest Management Act of 1976 provide strong guidelines for the management of federal lands. The main emphasis resulting from this legislation is the management for multiple resources on federal lands. Private rangelands are managed by the people who own them. The management of nonfederal rangelands is affected by federal statutes such as the



Figure 6.—Pack horses on rangelands (photo courtesy of Pat Aguilar, USDA Forest Service).

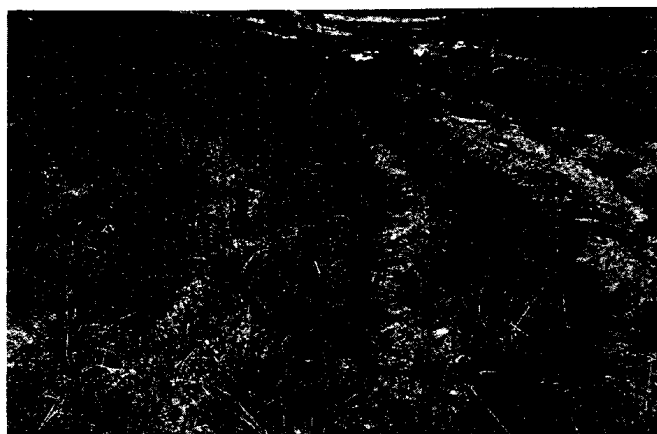


Figure 7.—Wheatgrass contours on reclaimed mineland in New Mexico (photo by Earl Aldon, USDA Forest Service)

“sodbuster” and “swampbuster” provisions of the Food Security Act of 1985.

Forest and Rangeland Area

Nationally, rangelands represent 34%, or 770 million acres, of the total land base of the United States (Bones in press). Forest lands occupy 32%, whereas pasture and cropland area represents 24% of the Nation's land base. The remaining 10% is classified as human-related land. Thus, over 35% of the Nation's land base has been converted from forest and rangeland for uses such as cropping, roads, industrial areas, and cities.

The present location and area of range and forest land is a function of the historical and current land use within each region of the United States (fig. 8). As the United States was first settled, large areas of eastern deciduous

Table 5.—Area (1,000 acres) of forest and rangeland in federal and nonfederal ownerships.

Region	Regional total	Forest ¹			Rangeland		
		Total	Nonfederal	Federal	Total	Nonfederal	Federal
Rocky Mountains	555,725	142,329	46,760	95,569	413,396	242,485	170,911
Pacific Coast	169,079	101,039	34,036	67,003	68,040	33,212	34,828
Southern	314,850	199,096	179,966	19,130	115,754	115,557	197
Northern	165,987	165,561	152,612	12,949	426	254	172
Alaska	291,780	119,045	101,338	17,707	172,735	102,435	70,300
U.S. total	1,497,421	727,070	514,712	212,358	770,351	493,943	276,408

¹Forest land includes transition land.

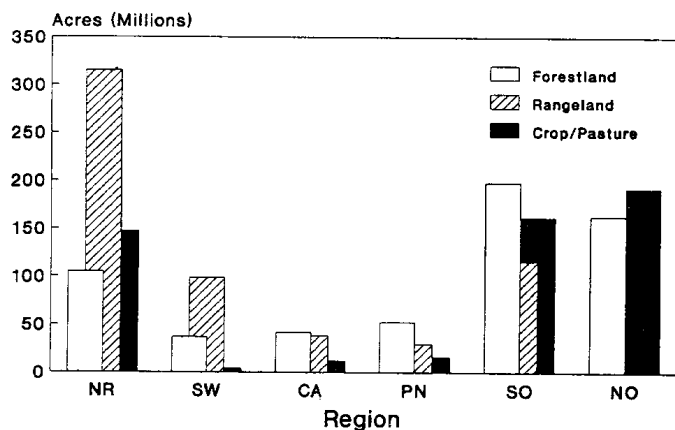
Source: Darr (in press) for rangeland; Bones (in press) for forest land.

forest in the NO region were converted to cropland and then to urbanland. As of 1972, over 70% of maple-basswood and beech-maple forests within the maple-beech-birch ecosystem (fig. 2) had been converted to urban, cropland, or pasture (Klopatek et al. 1979). Large areas of productive agricultural land occur on sites formerly occupied by oak-hickory or prairie ecosystems (fig. 2) in Indiana, Illinois, and Iowa. The results of this land conversion is more land in cropland and pasture than in forest in the NO region (fig. 8). Commercial forest land, rangeland, and cropland/pasture are found in the SO region (fig. 8). These forest and range ecosystems provide much of the Nation's timber, along with hunting opportunities for white-tailed deer and wild turkey, and forage for livestock (table 4). Diverse range ecosystems still occur in the southern and western parts of the SO region (fig. 2). The eastern part of the NR region and the western parts of the NO and SO region are referred to as the Great Plains. Over 85% of the prairies dominated by bluestem grass have been converted to pasture and cropland (Klopatek et al. 1979). Agricultural economics and irrigation have fostered the conversion of the plains grassland to cropland (Huszar and Young 1984). The NR region has nearly the same acreage in cropland and pasture as in forest, however, both are overshadowed by rangeland area (fig. 8). In the western United States, the

intermix of large forested areas with rangeland, along with the predominance of federal ownership, provides recreation, water, timber, grazing, and minerals management opportunities (tables 2 and 3). With few exceptions, less than 20% of the natural vegetation in these western regions have been converted to urban or other uses (Klopatek et al. 1979). Forest or rangeland acreages are dominant in the NR, the SW, and the PN (fig. 8). The PN and CA regions have large areas of forest and rangeland that provide much commercial timber, forage, and recreational use (table 3).

Because the impact of humans has had a long history in many parts of the United States, undisturbed examples of these ecosystems are managed as Research Natural Areas (RNA's) on NFS lands (Peterson and Rasmussen 1985). The principal management goals are to preserve a representative array of all significant ecosystems as sources of baseline data, to provide sites for the study of natural processes in undisturbed ecosystems, and to provide gene pool preserves for plant and animal species (Peterson and Rasmussen 1985). Because FRES ecosystems represent groupings of many vegetation types, more than one RNA exists for some forest and range ecosystems. Finer delineations of the oak-hickory ecosystem include the yellow poplar-hemlock type in Alabama and the post oak-black oak type in Ohio (table 6). The broad geographic range of the lodgepole pine ecosystem is represented by RNA's in Oregon, Montana, and Wyoming (table 7). The diversity of wet grassland ecosystems is protected in eastern states such as Delaware, southern states such as Florida and Texas, and western states such as Montana and New Mexico (table 8). While many National Forests have RNA's, some ecosystems are found only on other ownerships, for example the shinery ecosystem on BLM-administered lands in New Mexico.

The conservation of habitat is the most cost-efficient manner to protect large numbers of plant and animal species and associated ecological processes. This conservation includes, not only the ecological reserves such as Forest Service RNA's, but also management strategies to protect and restore nonreserve habitat (Conservation Foundation 1987). In the United States, some form of protection exist on nearly 7.2% of the land (Conservation Foundation 1987). This estimate includes federal areas such as RNA's as well as state and private reserves (Juday 1988).



NOTE.—Forest includes transition land.

Source: Darr (in press)

Figure 8.—Forest, rangeland, crop, and pastureland by assessment regions in the United States, 1983.

Table 6.—Research natural areas in eastern forest ecosystems on federal lands.¹

FRES type	SAF type	National forest and state
White-red-jack pine	Eastern hemlock	Allegheny, Pennsylvania Upper Peninsula EF, Michigan George Washington, Virginia
	Red pine	Chippewa, Minnesota
	Eastern white pine	Superior, Minnesota
	Hemlock-yellow birch	Hiawatha, Michigan
Spruce-fir	Red spruce	White Mtn., New Hampshire
	Balsam fir	Superior, Minnesota
Loblolly-shortleaf	Shortleaf pine	Daniel Boone, Kentucky
Oak-pine	Loblolly pine-hardwood	Mississippi, Mississippi
Oak-hickory	Yellow poplar-hemlock	William Bankhead, Alabama
	White-black-northern red oak	Talladega, Alabama
		Ouachita, Arkansas
		Pisgah, North Carolina
	Post oak-black oak	Wayne Hoosier, Ohio
	Chestnut oak	George Washington, Virginia
	Northern red oak	Chequamegon, Wisconsin
Oak-gum-cypress	Sweet bay-swamp tupelo	Osceola, Florida
	-red maple	
	Overcup oak-water hickory	Mississippi, Mississippi
	Baldcypress-water tupelo	Kisatchie, Louisiana
	Sweetgum-willow oak	Francis Marion, S. Carolina
	Water-swamp tupelo	Francis Marion, S. Carolina
Elm-ash-cottonwood	Sugarberry-American elm	Mississippi, Mississippi
	-green ash	
Maple-beech-birch	Sugar maple	Upper Peninsular EF, Michigan McCormick EF, Michigan Superior, Minnesota
	Beech-sugar maple	Wayne Hoosier, Indiana
	Sugar maple-beech-yellow birch	Pisgah, North Carolina
Aspen-birch	Paper birch	Chippewa, Minnesota

¹The Society of American Foresters (SAF) type with the most acres was used to classify the RNA. EF is experimental forest located on a national forest.

Sources: Franklin et al. (1972a, 1972b); National Science Foundation, Federal Committee on Ecological Reserves (1977); Peterson and Rasmussen (1985); Shanklin (1960).

Land Grazed by Wild and Domestic Herbivores

Grazing is a natural process in most ecosystems. Before European settlement, North American ecosystems were grazed by large numbers of wild herbivores, such as antelope, bison, deer, and elk. Climax vegetation evolved with a complex set of relations between plants, animals, and fire. Since settlement, wild grazers and browsers have declined concurrent with the rise of domestic grazers and browsers (Joyce and Skold 1988, Wagner 1978). Early settlers and those who followed were a new ecological force that realigned the grazing influences already present. Wild grazers were replaced by increasing numbers of domestic grazers, and wild browsers by domestic browsers (Stoddart et al. 1975). Recognized as one of the important resources of rangelands, wildlife and their habitats have increased through recent multiple-use management (Committee on Impacts of Emerging Agricultural Trends on Fish and Wildlife Habitat 1982).

Assessing the land currently grazed by wild and domestic herbivores is a complicated process, hindered by the lack of appropriate data. Not all rangeland or forest land is grazed by large herbivores. Steep slopes, rocky outcrops, highly erosive sites, and flooded areas are unsuitable for grazing. Livestock grazing is prohibited on some ecological preserves and areas under special management. Islands of forest or rangeland may be surrounded by inhospitable environments, making their grazing use by wildlife inaccessible. The widespread distribution of large herbivores across the United States indicates a similar wide distribution of grazing-lands (figs. 4 and 8). National statistics for the area grazed by livestock are available for forest and pasture on nonfederal lands and some federal lands. These statistics provide a lower limit of the amount of land grazed by large herbivores.

Nationally, over 16%, or 74.7 million acres, of nonfederal forest land was grazed by livestock in 1982. The percentage of nonfederal forest land grazed in western

Table 7.—Research natural areas in western forest ecosystems on federal lands.¹

FRES type	SAF type	National forest and state
Douglas-fir	Interior Douglas-fir	Pike, Colorado Boise, Idaho Salmon, Idaho Coconino, Arizona Lolo, Montana
	Douglas-fir—hemlock	Willamette, Oregon Mount Hood, Oregon Mount Baker, Washington Gifford Pinchot, Washington Siskiyou, Oregon
	Port Orford-cedar	
Ponderosa pine	Interior ponderosa pine	San Juan, Colorado Black Hills, South Dakota Santa Fe, New Mexico Coconino, Arizona Wenatchee, Washington Winema, Oregon Malheur, Oregon Deschutes, Oregon Coronado, Arizona Fort Valley EF, Arizona Ochoco, Oregon Lassen, California Shasta Trinity, California Boise, Idaho Custer, Montana
	Ponderosa—sugar pine-	
	Douglas-fir	Rogue River, Oregon
	Pacific ponderosa pine-	
	Douglas-fir	Rogue River, Oregon
	Jeffrey pine	Inyo, California
	Western juniper	Modoc, California
	Arizona cypress	Coconino, Arizona Coronado, Arizona
Western white pine	Western white pine	Kaniksu, Idaho Flathead, Montana
Fir-spruce	Blue spruce	Uncompahgre, Colorado
	Engelmann spruce-	
	subalpine fir	Gunnison, Colorado Pike, Colorado Medicine Bow, Wyoming Cococino, Arizona Colville, Washington Willamette, Oregon Kaniksu, Idaho Manti-Lasal, Utah Arapaho, Colorado Gifford Pinchot, Washington Williamette, Oregon
	Bristlecone pine	
	Mountain hemlock	
	Grand fir	Mount Hood, Oregon Umatilla, Washington
Hemlock-Sitka spruce	Western hemlock	Tongass, Alaska Mount Baker, Washington Siuslaw, Oregon Olympic, Washington
	Hemlock-Sitka spruce	Tongass, Alaska Siuslaw, Oregon
	Western red cedar	St. Joe, Idaho
	Coastal true fir	Mount Hood, Oregon
	-hemlock	Mount Rainier, Washington Gifford Pinchot, Washington Williamette, Oregon
	Western red cedar-	Mount Baker, Washington
	western hemlock	Tongass, Alaska

Table 7.—Continued

FRES type	SAF type	National forest and state
Larch	Larch—Douglas-fir	Coer D'Alene, Idaho Lolo, Montana
Lodgepole pine	Lodgepole pine	Bighorn, Wyoming Wallowa-Whitman, Oregon Beaverhead, Montana
Redwood	Redwood	Siskiyou, Oregon Redwood EF, California
Western hardwoods	Oak-diggerpine	San Joaquin Experiment Range, California
	Aspen	Apache, Arizona Caribou, Idaho Wasatch, Utah
	Canyon live oak	Angeles, California
	Cottonwood-willow	Wasatch, Utah
	Interior live oak	Coronado, Arizona

¹The Society of American Foresters (SAF) type with the most acres was used to classify the RNA. EF is experimental forest located on a national forest.

Sources: Franklin et al. (1972a, 1972b); National Science Foundation, Federal Committee on Ecological Reserves (1977); Peterson and Rasmussen (1985); Shanklin (1960).

regions, 72% RM and 33% PC, was much higher than in the NO (6%) and SO (13%) regions (USDA Soil Conservation Service 1987a). The limited amount of non-federal forest land in the western regions tends to focus resource use on these lands. Much of the forest land in the SO region is used to produce timber and commonly is not managed for grazing, although opportunities for grazing livestock as a silvicultural tool are receiving closer examination (Doescher et al. 1987, Krueger 1987, Pearson 1987). The importance of pasture as a roughage source is evidenced by the extent of grazed pastures. More than 74% of all pasture in the United States was grazed in 1982 (USDA Soil Conservation Service 1987a). No estimates of the percentage of rangeland grazed were available for nonfederal land.

Not all land within the NFS allotments can be grazed. Only 49.6 million acres out of 99.8 million acres are suitable for grazing (USDA Forest Service 1988c). Suitable acres are those acres that can be grazed without sustaining damage to the range resource. Additional acres outside of NFS allotments are suitable for grazing, but no inventory estimates of these acres are available.

No estimate of suitable lands on BLM-administered lands is available. Thus, for this assessment, the acreage estimate for grazed BLM-administered lands incorporates all acres within BLM allotments, over 171 million acres (tables 13 and 14 in USDI Bureau of Land Management 1987). An additional 51 million acres are grazed by livestock on other federal, state, and local agency lands in the western regions, providing over 7.1 million AUMs (Bartlett et al. 1983).

Unfortunately, the available information is insufficient to precisely determine acres grazed by large herbivores in the United States. No acreage information is available to estimate wild herbivore grazing nationally, or livestock grazing on rangelands. If it is assumed that all non-

federal rangeland is grazed, and the above acreage estimates represent the minimum federal land grazed, then over 841 million acres of forest and rangeland are grazed by livestock. This represents 70% of the forest and rangeland base, or 44% of the total land base (excluding Alaska). Cropland and pasture provide a significant amount of forage also but are not included here.

RANGE VEGETATION

Vegetation on range and forest land is a function of climate, fauna, and soils. The management of vegetation affects the total production and composition of plant species which in turn affects the mix of range outputs. The vegetation within some forest and range ecosystems has been altered by overgrazing, disruption of the natural fire cycle, invasion of exotic plant or animal species, alteration of the flow regime from the diversion of water, disturbance from mining, and recreational use.

Range Condition and Ecological Status

Traditionally, the term "range condition" has been used as a measure of the health of the range ecosystem. Range condition has been defined as the extent of departure from the climax vegetation of a site (Stoddart et al. 1975). Early measurements involved a comparison of species present with species of the climax community. A large departure implied poor condition. This rating was based on the susceptibility of the plant species to grazing, and by this definition, a direct cause and effect relation was assumed between livestock overgrazing and the status of vegetation in a deteriorated range. The concept of range condition was difficult to apply to forested

Table 8.—Research natural areas in range ecosystems on federal lands.¹

Ecosystem	National forest and state
Sagebrush	Snoqualmie, Washington Beaverhead, Montana
Desert shrub	Gila, New Mexico Tonto, Arizona Desert Experiment Range, Utah
Shinnery	Roswell District, BLM, New Mexico
Texas savanna	Laquna Atascosa NWR, Texas
Southwestern shrubsteppe	Bosque del Apache NWR, New Mexico
Chapparral-mountain shrub	Okanogan, Washington Mendocino, California Sierra, California
Pinyon-juniper	Inyo, California Toiyabe, Nevada
Mountain grasslands	Umatilla, Washington
Mountain meadows	Gifford Pinchot, Washington
Plains grasslands	Commache Grasslands, Colorado Custer, North Dakota
Prairie	Nebraska, Nebraska
Desert grasslands	Coronado, Arizona
Wet grasslands	Bombay Hook NWR, Delaware Loxahatchee NWR, Florida Brazoria NWR, Texas Bosque del Apache NWR, New Mexico Lolo, Montana
Annual grasslands	San Joaquin Experiment Range, California
Alpine	Inyo, California

¹The type with the most acres was used to classify the RNA. SAF types were not available for range ecosystems. When no RNAs existed for an ecosystem on National Forest System lands, sites managed by other federal agencies were given. NWR is National Wildlife Refuge administered by USDI Fish and Wildlife Service. BLM is Bureau of Land Management.

Sources: Franklin et al. (1972a, 1972b); National Science Foundation, Federal Committee on Ecological Reserves (1977); Peterson and Rasmussen (1985); Shanklin (1960).

ecosystems, and did not address the impacts on vegetation of other uses of rangeland and forest ecosystems. In addition, the Range Inventory Standardization Committee (1983) pointed out that most vegetation and its physical environment has been disturbed by past use such that the potential natural community (PNC) of the site differs from the original pristine climax plant community.

Two concepts are important in the assessment of forest and rangelands: (1) the maintenance of the long-term productive potential of the site; and (2) the present level of production relative to the potential for a specific use, such as livestock grazing or wildlife habitat (Range Inventory Standardization Committee 1983). The Range Inventory Standardization Committee proposed that ecological status, and a resource value rating be used to assess these two concepts. Ecological status is use-independent whereas a resource value rating is the value of the vegetation for a particular use, such as wildlife habitat or domestic grazing.

Ecological status is a measure of the successional stage of the site. Natural disturbances, such as drought, wild fires, grazing by native fauna, and insects are a natural part of the development of any plant community. Once disturbed and if left without further perturbation, the plant community undergoes a change in function and structure to develop a climax community or PNC (Range Inventory Standardization Committee 1983). The stages of the successional path are referred to as early seral, midseral, late seral, and PNC. The resource outputs vary with each stage, thus management decisions may favor one stage over another, because some successional stages are more productive with respect to the desired resource outputs. The difference between climax, as traditionally used, and PNC reflects the conditions existing today where much of the Nation's vegetation has been altered by past use, including species introductions, grazing, cropping, or logging. On some sites, the PNC will be very different from the climax vegetation type (Range Inventory Standardization Committee 1983).

Because the use of ecological status and resource value ratings represent a departure from the traditional inventory measurements, a time lag will exist before resource inventories may incorporate this approach to measuring range vegetation. Therefore, the current status of range condition must be discussed in light of the definitions used in the existing inventories from different federal agencies.

The Soil Conservation Service (SCS) inventories non-federal rangelands, and defines range condition as:

...the present state of vegetation of a range site in relation to the climax (natural potential) plant community for that site. It is a expression of the relative degree to which the kinds, proportions, and amounts of plants in a plant community resemble that of the climax plant community for the site (USDA Soil Conservation Service 1976).

The BLM has used different definitions of range condition (Box et al. 1976), but in 1984, BLM reported that future condition estimates would be based on the definitions of ecological status and resource value ratings given above (USDI Bureau of Land Management 1984). Thus, the 1986 figures for range condition reflect ecological site inventory data on about 52% of the BLM-administered lands, plus range condition estimates based on earlier inventories and professional judgment on the remaining lands. The BLM describes range condition on their lands as similarity with the PNC: excellent = 76-100% similarity, good = 51-75%, fair = 26-50%, and poor = 0-25% (USDI Bureau of Land Management 1987).

The FS uses ecological status to describe rangeland and forest ecosystems on NFS lands (USDA Forest Service Service Range Management Staff 1986). Ecological status is rated by one of the following categories: PNC, late-seral, midseral, and early-seral stages. These categories are not equivalent to the range condition categories of excellent, good, fair, and poor. Ecological status relates the vegetation to the potential vegetation, not the usefulness of the vegetation to a particular use such as grazing. The usefulness of the vegetation for grazing is assessed by the resource value rating for livestock forage. A satisfactory livestock forage rating is defined as follows: adequate protection for soil, acceptable levels of forage species composition and production or acceptable trend in composition and production for the intended use.

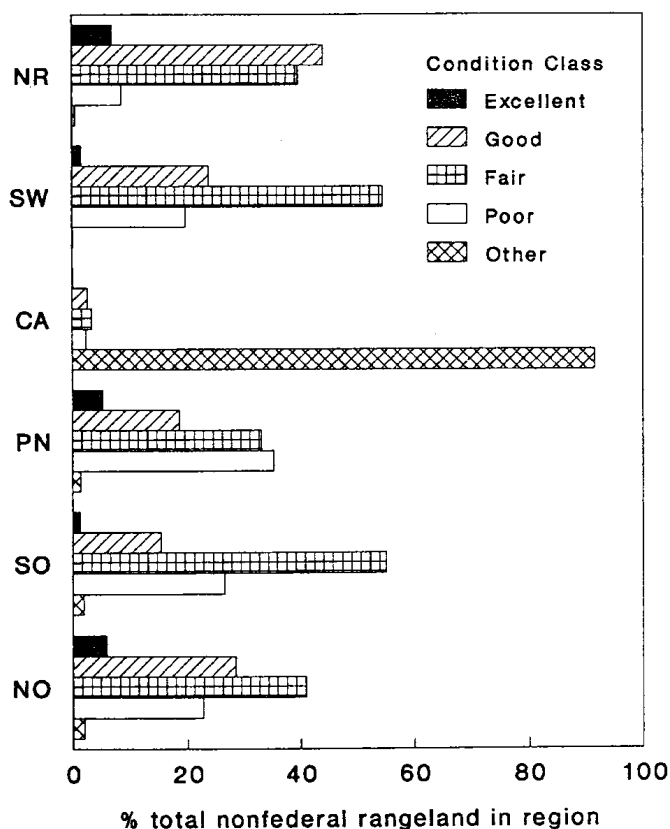
Range condition establishes the current status of the vegetation, and the term "trend" has been used to assess the direction of change of the current community with respect to PNC. Again, these definitions vary by resource inventory. The SCS defines trend as the direction of change in range condition, and measures apparent trend through species composition changes, abundance of seedlings and young plants, plant residues, plant vigor, and the condition of the soil surface (USDA Soil Conservation Service 1976). The FS defines trend in relation to direction of change in ecological status, that is movement toward, away from, or no change with respect to PNC.

Condition of Nonfederal Rangelands

As reported by USDA Soil Conservation Service (1987c), range condition as a percentage of the total non-federal rangeland base (excluding Alaska) in 1982 was as follows: excellent, 4%; good, 31%; fair, 47%; and poor, 17%. In figure 9, the Other category reflects lands for which range condition ratings have not been assigned such as the annual grasslands of California and areas elsewhere seeded to and dominated by introduced species (USDA Soil Conservation Service 1987c).

The SCS reported that at the national level, the trend in condition of rangelands in the private sector was static on 69% of the land, up on 16%, and down on 15%. The SCS Second Appraisal suggested that, although inventory methods differ considerably, the last three SCS range assessments (1963, 1977, and 1982) indicated that the condition of nonfederal range is improving (USDA Soil Conservation Service 1987c).

Region



Source: USDA, Soil Conservation Service (1987c)

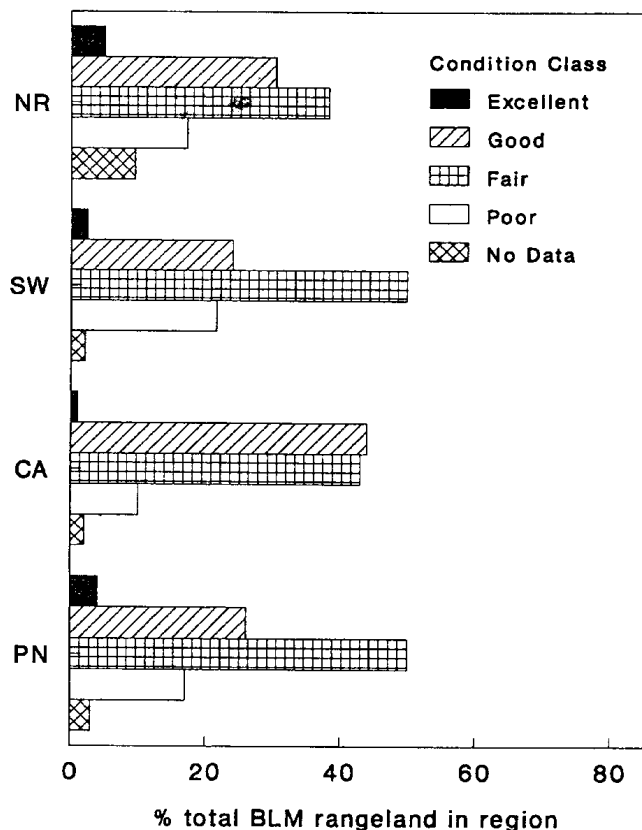
Figure 9.—Range condition on nonfederal rangelands by assessment regions in the United States.

Condition of Bureau of Land Management-Administered Lands

In 1986, the condition of BLM-administered rangelands at the national level in terms of percentage of total rangeland was: excellent, 4%; good, 30%; fair, 41%; and poor, 18%. These numbers do not include 7% of BLM-administered lands which were unsuitable for grazing or for which data or estimates of condition were unavailable (table 16 in USDI Bureau of Land Management 1987). Alaska was also not included. Condition on BLM-administered lands by assessment regions is shown in figure 10.

Trend information on BLM-administered lands was not available, however data from a number of historical reports were reviewed and compiled into similar categories by Box et al. (1976) and Box (1988). Although these data suggest that condition is improving, Box et al. (1976) stressed that different techniques were used and comparisons are difficult to make. Better inventory data would be valuable (Box 1979).

Region



Source: USDI, Bureau of Land Management (1987)

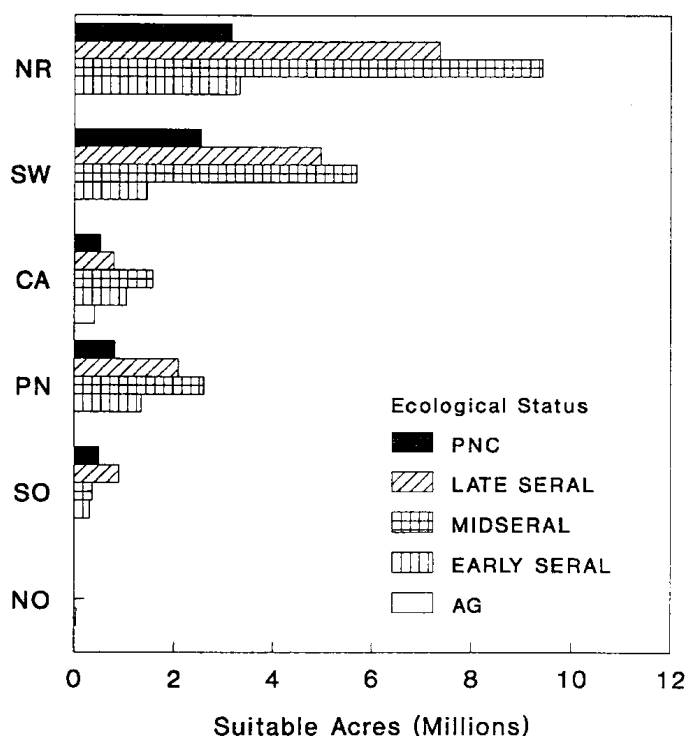
Figure 10.—Range condition on Bureau of Land Management-administered land by assessment regions in the United States.

Condition of National Forest System Lands

A summary of the ecological status of NFS lands nationally indicates that 15% of all NFS lands are at PNC, 31% in late-seral, 38% in midseral, and 15% in early-seral. These numbers do not include annual grasslands (0.8%). The regional distribution of ecological stages varies (fig. 11). The western and southern regions have large amounts of forest land. Timber harvesting and clearcutting place the site in an earlier successional stage, allowing for increased production of herbaceous and shrubby species. Regions with less commercial timber, more grass and shrubland, and a history of grazing tend to have a clumped distribution of acres in the mid-seral or late-seral stages (fig. 11).

With respect to livestock management, the resource value rating of NFS lands at the national level indicates that 80% are in satisfactory management and 20% are in unsatisfactory management. The early-seral and midseral stages have more lands in unsatisfactory management (fig. 12). In some forest types, early-seral and midseral stages have a more productive herbaceous understory than late-seral or PNC, and thus, these stages would be grazed more often.

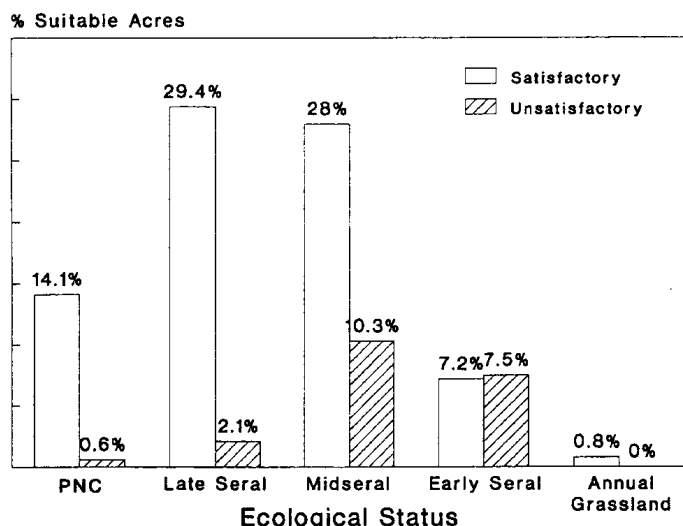
Region



NOTE.— AG = annual grasslands.

Source: USDA, Forest Service (1986b)

Figure 11.—Ecological status for National Forest System lands by assessment regions in the United States.



Satisfactory = lands with adequate soil protection, forage species composition and production, and acceptable trend in forage species

Source: USDA, Forest Service (1986b)

Figure 12.—Livestock forage value rating within ecological status on National Forest System lands.

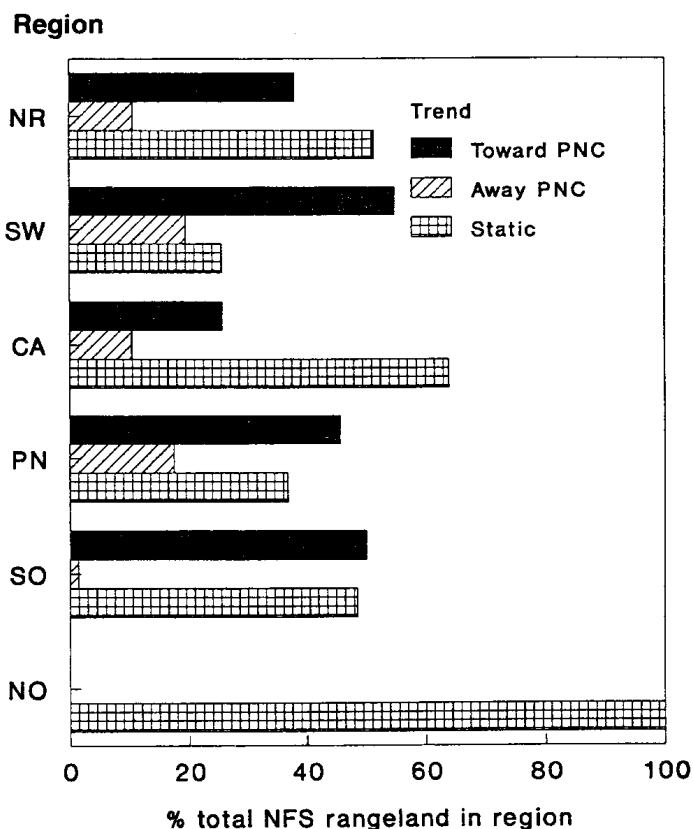
At the national level, 43% of NFS lands have a static trend in ecological status, 14% are moving away from PNC and 43% are moving toward PNC. The regional numbers follow the national trend; most of the acres are either moving toward PNC or are static (fig. 13). The SW region has the greatest percentage of acres moving away from PNC, a reflection of 400 years of grazing, and severe overgrazing at the turn of the century. Substantial improvements have been made in this region, as indicated by the large percentage of acres moving toward PNC.

Forage Available for Livestock Grazing

The national production of forage is difficult to quantify. As discussed in detail in Chapter 2, forage production is a function of the available land, productivity, and the management of that land. As management can significantly affect the quantity produced, and the implementation of range technology has not been nationally inventoried, a determination of the production of forage is difficult. As reliable livestock inventories are available, however, forage consumed by livestock can be estimated and interpreted as a lower estimate of the forage produced on rangelands and forest lands. The permitted and leased grazing on public lands provides an additional estimate of the supply of forage from these lands.

Permitted or Leased Range Forage

The NFS permitted 10.1 million Animal Unit Months (AUMs) to be grazed in 1985 and 1986 (USDA Forest Service 1986b, 1987b). The RM Region supplied most of these AUMs (table 9). The BLM permitted 13.5 and 12.5 million



Source: USDA, Forest Service (1986b)

Figure 13.—Trend in ecological status on National Forest System lands by assessment regions in the United States.

AUMs³ to graze in 1985 and 1986, respectively (USDI Bureau of Land Management 1986, 1987). The RM region supplied the majority of these AUMs also (table 9). Comparisons with the AUMs reported from other federal, state, and local agencies (Bartlett et al. 1983) indicate that the NFS and the BLM are the predominate suppliers of forage in the public sector. These other public owners supplied slightly more than 7 million AUMs.

Consumption of Grazed Forages in Livestock Production

Beef cattle and sheep represent the largest inventories of livestock that use grazed roughages in the United States. Dairy cattle, goats, horses, and hogs use grazed forages, but their consumption is less than 5% of the total forage consumed annually. Although actual feed consumption figures are not available, USDA estimated that less than 1% of the feed costs for dairy cows is used for pasture (Gee and Madsen 1988). The 1.5 million goats consume about 3.6 million AUMs of grazed forages (Gee

³Animal unit months (AUMs) are defined differently by FS and the BLM. For this report, an animal unit month (AUM) is the forage required to sustain one animal unit for 1 month where one animal unit is considered to be one mature cow or equivalent. For this report, the FS's definition of AUMs was used and BLM AUMs were converted to a unit that is similar to FS AUMs by multiplying the BLM Animal Months (AMs) by 1.2 (USDA Forest Service and USDI Bureau of Land Management 1986).

Table 9.—Number of permitted AUMs on public lands by region, 1985, 1986.

Region	Forest Service	Bureau of Land Management ¹	Total
1985			
Northern Rocky	5,928,000	8,938,800	14,866,800
Southwest	2,504,000	2,715,600	5,219,600
Rocky Mountains	8,432,000	11,654,400	20,086,400
California	621,000	464,400	1,085,400
Pacific North	745,000	1,222,800	1,967,800
Pacific Coast	1,366,000	1,687,200	3,053,200
Southern	248,000	— ²	248,000
Northern	79,000	— ²	79,000
Total	10,125,000	13,341,600	23,466,600
1986			
Northern Rocky	5,906,000	8,263,200	14,169,200
Southwest	2,510,000	2,656,800	5,166,800
Rocky Mountains	8,416,000	10,920,000	19,336,000
California	592,000	493,200	1,085,200
Pacific North	748,000	1,122,000	1,870,000
Pacific Coast	1,340,000	1,615,200	2,955,200
Southern	239,000	— ²	239,000
Northern	78,000	— ²	78,000
Total	10,073,000	12,535,200	22,608,200

¹Bureau of Land Management AUMs were converted to a unit that is similar to Forest Service AUMs by multiplying by 1.2 (after USDA Forest Service, and USDI Bureau of Land Management (1986)).

²No land managed for grazing by BLM in this region.

Source: USDA Forest Service (1986b, 1987b); USDI Bureau of Land Management (1986, 1987).

and Madsen 1988). This number is small in comparison with the total AUMs consumed by beef cattle and sheep. Although hogs use some grazed roughages, USDA estimated that less than 1% of hog feed costs are for pasture (Gee and Madsen 1988). The estimated 2.0 million horses (fig. 4) also represent a small demand for grazed roughages relative to beef cattle and sheep. Although recreational horses outnumber work horses, the grazed roughages demand from recreational stock is minor as hay and concentrate comprise most of their feed mix (Smith et al. 1986).

Grazed forages consumed by beef cattle and sheep include deeded nonirrigated rangeland and pasture, publicly owned grazing land, deeded irrigated pasture, and crop residues. National estimates of forage consumption by beef cattle and sheep (table 10) are derived from USDA Economic Research Service livestock enterprise budgets (Gee et al. 1986a, 1986b). The structure of these budgets is based on the 1981 national survey conducted by the USDA Statistical Reporting Service in which detailed estimates were made of feed consumption by type of feed and season of use. Nationally, beef cattle consume about 96% of the estimated total grazed forages (table 10). In 1985, total grazed forages for beef cattle were supplied primarily by the private sector; 87% came from deeded nonirrigated grazing land, 6% from public land, 5% from crop residues, and 2% from irrigated pasture. In contrast to this distribution, the supply of grazed forages for sheep was

predominately from deeded grazing land (60%) and public land (28%). Consumption of grazed forages in livestock production is examined in detail in Chapters 2 and 3.

INTERNATIONAL RANGE RESOURCE

Rangeland and pasture comprise a major portion of the land base in many of the world's countries (fig. 14). For Africa, Asia, and Oceania, rangeland and permanent pasture is the dominant land cover (Food and Agriculture Organization 1986). The use of these lands is determined by the ecology and economy along with the customs and traditions of individual countries. If the lands are grazed, cultural traditions also influence the type and mix of domestic animals (Rourke 1986, 1987). Livestock numbers are greatest in Asia, a reflection of its large land mass, extensive area of permanent pasture, and additional forage available from cultivated cropland (fig. 15). Africa, with the largest amount of land in permanent pasture of all the world's regions, is second only to Asia in the number of sheep, goats, buffaloes, and camels (Food and Agriculture Organization 1986).

Use of the range resource in the United States is affected by the global use of land, and in particular, the global range resource. The United States interaction with global rangelands occurs through the market place, political systems, and education. As discussed in more detail

Table 10.—Grazed forage consumption (1,000 AUMs and percentage of total) by beef cattle and sheep in the United States, 1985.

Source of grazed forage	Cattle	Sheep	Total
Deeded Land			
Non-irrigated	359,359 (87.2)	10,742 (56.3)	370,101 (85.8)
Irrigated	8,557 (2.1)	725 (3.8)	9,283 (2.2)
Public land	24,163 (5.9)	5,304 (27.8)	29,467 (6.8)
Crop residue	20,011 (4.8)	2,302 (12.1)	22,312 (5.2)
Total	412,090	19,073	431,163

Source: Gee and Madsen (1988).

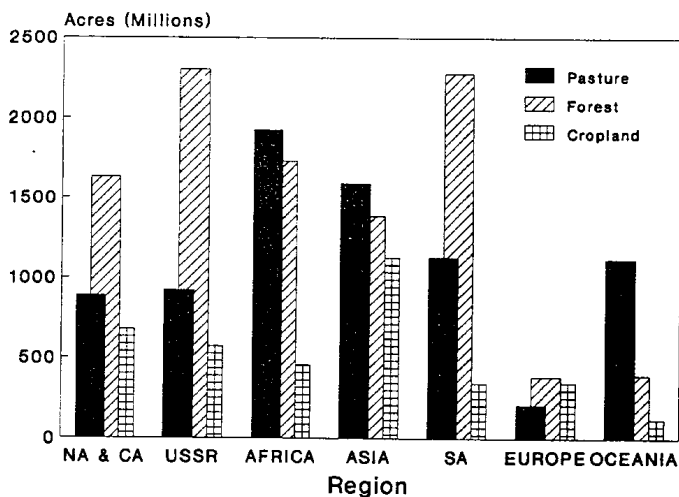
in Chapter 3, about 8% of the meat consumed in the United States is imported, and 1.5% of the meat produced in the United States is exported (USDA Economic Research Service 1986). Through our political system about \$0.9 billion of U.S. foreign aid is allocated for food aid, and over \$6 billion for development assistance which includes food loans and grants, and technical assistance projects (Meiman 1988). Although credit for increasing self-sufficiency in food production has been given to university outreach programs and the Green Revolution (Meiman 1988), recent range and livestock programs have been poorly evaluated (Thomas 1987). One reason for poor success has been the inability of development programs to recognize local cultural and ecological systems which may be very different from western traditions and temperate ecosystems (Ellis and Swift 1988). Future development projects will need to understand the cultural and ecological systems before establishing projects.

The Food and Agriculture Organization (1977) concluded that available world food supplies should be sufficient to provide everyone with an adequate diet if the problem of distribution could be solved. In The

Global 2000 Report to the President, projections for food and agriculture suggested a continuation in the growing importance of variability in supply (Council of Environmental Quality and USDS 1980). Expansion of agriculture into marginal areas increases the susceptibility of crop production to weather fluctuations, and in the future a larger proportion of the world's food supplies will be dependent on favorable (above average) rather than average rainfall and temperature (Council on Environmental Quality and USDS 1980).

The results of a recent United Nations report indicate that desertification is extending in area and intensity world-wide (fig. 16) (UNEP 1984). As of 1984, 35% of the earth's land surface and 20% of the earth's human population were considered to be threatened by encroaching deserts (Marbutt 1984). At least 35% of this total land surface has lost more than 25% of its productivity and is in serious need of reclamation (Karrar 1984, Marbutt 1984).

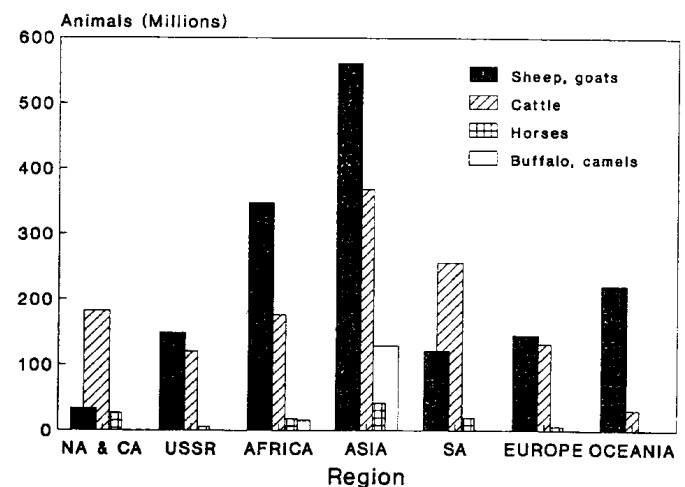
Over 7,600 million acres is at least moderately desertified and half of the world's rangeland is in severe or very severe desert conditions (Marbutt 1984). The proportion is higher (>60%) in developing regions, and



NOTE.—Oceania = Australia, New Zealand, South Pacific Islands. NA, CA, SA = North, Central, South America.

Source: Food and Agriculture Organization (1986)

Figure 14.—Forest, permanent pasture (tame, native, and rangeland), and cropland area of the world, 1984.



NOTE.—Oceania = Australia, New Zealand, South Pacific Islands. NA, CA, SA = North, Central, and South America.

Source: Food and Agriculture Organization (1986)

Figure 15.—Number of sheep, goats, cattle, horses, buffalo, and camels in 1985 by major regions of the world.

Region	Range	Rainfed Croplands	Irrigated lands	Forest Woodlands	Ground-water Resources
Sudano-Sahelian	↗	↓	↖	↓	↘
Africa S of Sudano-Sahelian	↓	↓	↖	↓	→
Med. Africa	↘	↘	↖	↘	↘
W Asia	↘	↘	↖	↘	↗
S Asia	↗	↓	↖	↓	→
USSR in Asia	↙	↙	↙	↗	→
China & Mongolia	↙	↖	↙	↘	→
Australia	→	→	↖	→	→
Med. Europe	↙	↖	↙	↗	→
S America	↗	↗	↖	↓	↘
Mexico	→	↓	↖	↓	↘
N America	↙	↙	↙	↗	↘

Source: after UNEP (1984) ↓ accelerating ↘ continued → unchanged ↗ improving

Figure 16.—Regional trends of desertification within land-use and major natural resources.

lower (<40%) in the developed regions such as North America and Australia. Rangeland areas of immediate concern are the interfaces between the semi-arid grazing-lands and the densely-populated rain-fed croplands. Agriculture is encroaching upon grazinglands, restricting livestock and wildlife to smaller areas. Other areas of concern are the interfaces between semi-arid and sub-humid mixed farming areas in hilly tracts, as in Africa south of the Sudano-Sahelian region and in Andean South America. In developed regions, the invasion of woody vegetation of low pastoral value was considered to be the major problem of rangelands (Marbutt 1984). Increased population growth coupled with increasing poverty in many countries has and will continue to put pressure on range vegetation and plant species survival (Lucas and Synge 1981). This pressure comes at a time when research on new or alternative agricultural and industrial crops has increasingly turned to the vast unstudied plant resources of the tropical zones (Plotkin 1988).

SUMMARY

Range and range resources mean many things to many people. Range vegetation is defined as grasses, grass-like plants, forbs, and shrubs. When the plant community is dominated by this type of vegetation, the land is referred to as rangeland. Although rangelands predominate in western United States as natural grasslands, shrublands, savannas, deserts, tundra, alpine, coastal marshes, and wet meadows, rangelands in the eastern United States occur as tallgrass prairie, marshes, or wet meadows. Riparian ecosystems and plant communities dominated by introduced species are also considered rangeland. About 34% or 770 million acres of the total land base in the United States is rangeland.

Range vegetation is the building block for multiple resource outputs from rangelands and forests. Range outputs include native plants for agricultural, reclamation, or landscaping purposes; forage for wild and domestic herbivores; habitats for wildlife, threatened and endangered plants and animals, and wild horses and burros; water; recreation; and minerals.

Range condition is reported by various federal agencies, and in light of the different definitions used in the current inventories, range condition is discussed for each reporting agency. The SCS reported condition as a percentage of the total nonfederal rangeland base in 1982: excellent, 4%; good, 31%; fair, 47%; and poor, 17%. The BLM reported 1986 figures as follows: excellent, 4%; good, 30%; fair, 41%; and poor, 18%. On NFS land, ecological status was reported as follows: 15% at PNC, 31% in late-seral, 38% in mid-seral, and 15% in early-seral. At the national level, 80% of NFS lands are in satisfactory management for livestock.

Forage consumed by livestock can be interpreted as a lower estimate of the forage produced on rangelands and forest lands. The NFS permitted 10.1 million AUMs to be grazed in 1985 and in 1986. The BLM permitted 13.5 and 12.5 million AUMs to be grazed in 1985 and 1986. Other public ownerships supplied less than 8 million AUMs.

Beef cattle and sheep represent the largest inventories of livestock that use grazed roughages in the United States. Dairy cattle, goats, horses, and hogs use grazed forage but their consumption is less than 5% of the total forage consumed annually. Nationally, beef cattle consume 431 million AUMs; 86% comes from deeded nonirrigated grazing land, 7% from public land, 5% from crop residues, and 2% from irrigated pasture. The supply of grazed forage for sheep was different than for cattle in that only 60% came from deeded grazing land and 26% from public land.

CHAPTER 2: FACTORS AFFECTING FORAGE PRODUCTION

INTRODUCTION

Production of Range Resource Outputs

Natural resource outputs, such as timber, forage for wild and domestic herbivores, water, and recreation are produced jointly from forest and rangeland ecosystems. Different management goals yield different mixes of these outputs. The national supply of these resources is a function of efforts in individual enterprises and on public lands. The future supply of these resource outputs is closely associated with their future demand. The future management of forest and rangelands in private and public ownerships will determine the future supply of these outputs.

Quantifying the future supply of these range resource outputs at the national level involves an analysis of factors underlying their production. The future national supply of outputs, such as native plants for harvest or cultivation, is difficult to quantify because the factors affecting demand or supply are local. The future supply of wildlife, wild horses and burros, and livestock is dependent on the future supply of forage. Range vegetation is fundamental in the joint production of many range outputs, including forage. This chapter focuses on quantifying the future supply of forage as a function of rangeland productivity and land availability for grazing. As many factors associated with forage demand influence production, future supply is closely related to future demand. Factors underlying supply (this chapter) and underlying demand (Chapter 3) are used to determine the future forage supply and demand at the national level (Chapter 4). A case study projecting the impact of resource management and land use changes on forage production at the regional level is presented (this chapter) as a potential method to analyze resource interactions in assessments.

Determinants of Forage Supply

Forage, that part of vegetation that is available for consumption by herbivores, is produced on forest land, rangeland, pasture, hayland, cropland (after crop harvest), and cropland used for pasture. Forage is produced

on private and public lands. Range vegetation covers the landscape naturally, and range management influences the quality and quantity of the forage component of range vegetation. Forage on forest and rangelands is typically produced with little or no agronomic practices, whereas forage on pasture or haylands may be intensively cultivated, seeded with improved species, irrigated, and fertilized. Where economically feasible, such management practices may be used to enhance forage production on forest and rangelands. Mechanically harvested forages from pasture or haylands are important in providing feed when grazed forages are unavailable.

The production of forage is undertaken with the expectation of some value accruing from the production effort (Tyner and Purcell 1985). Forage is used to produce livestock for meat and other products, wild horses and burros for preservation, and wildlife for recreation or preservation. The value attached to forage differs depending on the output, and the quantity of forage produced depends on the value of the output to the producer. Within a farm or ranch enterprise, forage production will be determined by the demand for livestock or wildlife (Glover and Conner 1988, Tyner and Purcell 1985). Nearly 78% of the forage consumed by livestock is produced from nonirrigated pasture owned by the livestock enterprises and, therefore, is not priced in a forage market (table 10). Thus, decisions to implement management practices to improve forage production will be based on the likely economic return associated with the final output, such as livestock or wildlife.

The amount of forage produced on public lands is set by multiple resource management objectives and public policy. Thus, the quantity produced on public lands will be a function of multiresource management for wild and domestic grazing animals and other resource outputs such as timber, water, recreation, and scenic beauty.

Assessing the forage produced nationally is difficult because forage production is not inventoried. Use, not production, is quantified when forage consumption estimates are derived from livestock inventories (table 10). Further, populations of wild grazing animals are not censused nationally as are livestock, thus deriving an estimate of the forage consumed by wild herbivores is also

difficult. Forage consumption represents only part of the forage produced on forest and rangelands. Physical inaccessibility may reduce grazing use of vegetation or, like the harvesting of timber on steep slopes, forage production may require additional expenses that make the utilization too expensive for the return. For example, the use of some areas by livestock often requires fencing to keep animals from grazing nearby palatable crops (Tyner and Purcell 1985), or areas may go unused by wild herbivores because of proximity to urban activities.

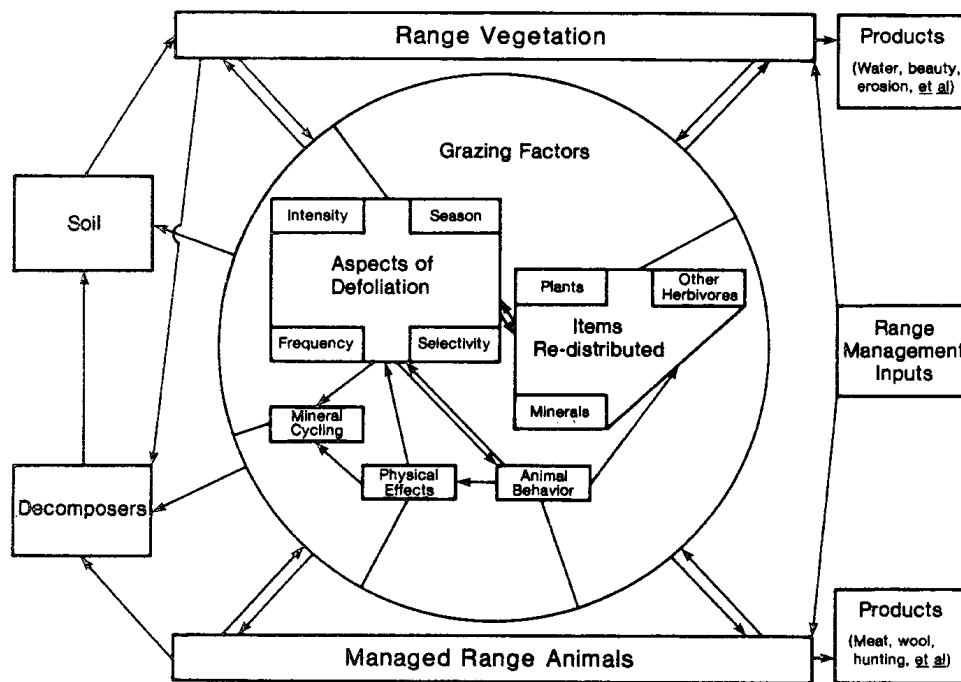
The national supply of forage is a function of the current and likely future management on forest and rangelands and the current and projected inventory of land available for forage production. Management results are influenced by the ecology of these forest and rangeland ecosystems. Past and current management includes grazing, timber harvesting, mining, cropping and the abandonment of cropland, and species introduction. These uses have and will affect the current production and potential production. Multiresource management requires a consideration of the tradeoffs in resource production. Future management practices, new technology, and eventually biotechnology, offer possibilities to enhance the future productivity of forest and rangelands. The availability of land for forage production is a function of the demand for land for other uses. Conversion of forest and rangeland to uses such as cropland or a

non-reversible use such as urbanland decreases the land available for forage production.

Forage production projections will be derived from projections of the likely future technological improvements in forage production and projections of land available for forage production. The present chapter discusses the impact of technology and land availability as they have historically affected the production of forage at regional and national levels.

DYNAMIC NATURE OF ECOSYSTEMS

Range ecosystems are diverse and complex systems involving the flow of energy and the cycling of minerals through primary producers (range vegetation), herbivores (livestock, big game, nongame), and the detrital system (decomposers involved in the breakdown of organic matter) (fig. 17). The diversity of ecosystems across the United States is evident (fig. 2). These ecosystems have evolved to survive erratic precipitation, extreme temperatures, and natural disturbances (such as fire). As ecosystems respond to natural or human-caused disturbances, plant and animal species may change. These shifts in community structure are referred to as succession. The production of certain outputs, such as forage for wild and domestic herbivores, may require that the



Source: after Heady (1975)

Figure 17.—Vegetation influences range animals and animals influence range through a number of interacting factors.

ecosystem be managed for an earlier stage than the Potential Natural Community (PNC). The biotic and abiotic processes within ecosystems induce a spatial heterogeneity across forest and rangelands (Risser et al. 1984) and link site-specific land management activities with the surrounding landscape. The management of spatial and temporal heterogeneity or biodiversity requires an understanding of the spatial and temporal aspects of natural disturbances such as fire, and management such as livestock grazing, timber harvesting, or recreation. Manipulation of these systems and the maintenance of biodiversity requires an understanding of the underlying ecological processes, their response to intensive or extensive management, and the consequences of management in the range and forest landscape.

Climate

Weather and soil are the primary abiotic factors affecting forage production on forest and rangelands (Eckert and Klebesadel 1985, Herbel and Baltensperger 1985, Marbel et al. 1985, Moore and Lorenz 1985). Whereas the average precipitation of the United States is about 30 inches, annual precipitation is less than 1 inch in parts of the arid West, greater than 60 inches in southern Florida, and nearly 400 inches on some Hawaiian islands (Guldin in press). The eastern United States has an annual average greater than 40 inches, whereas most of the western United States receives less than 20 inches of precipitation annually. These averages suggest that different plants and different adaptations by plants to climate are made across the United States.

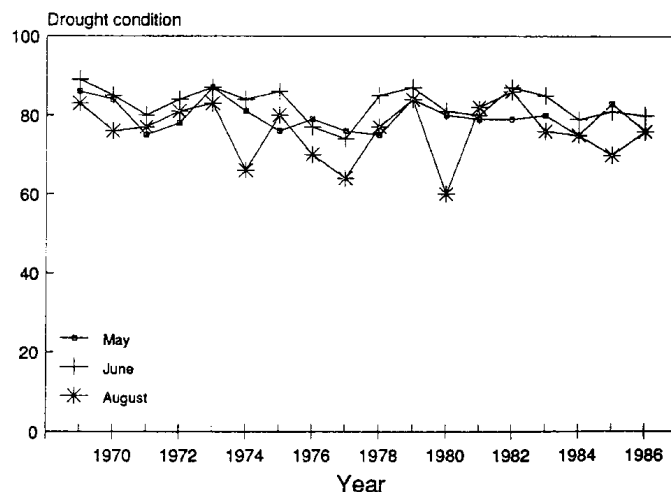
Average precipitation is derived from the tabulation of many years of data. Actual values of annual precipitation can range from zero to many times the annual average. The extremes, not the means, are the potentially harmful climatic events (Waggoner 1988). Drier climates are relatively more variable than wet ones, and changes in a drier climate will bring relatively more variation in annual precipitation (Waggoner 1988). Droughts can occur anywhere in the United States, and there is usually an area of drought each year (Trenberth et al. 1988). Western droughts have been numerous in the historical past: 1888-90, 1892-94, 1898-04, 1901, 1910, 1917, 1919, 1924, 1928-34, 1936, 1953-56 (Coupland 1958, U.S. Senate 1936). The more widespread dry years of the 1930's have been referred to as the "dust bowl years." Early records described the frequency of drought to be at least one or two years in every 10 years in western United States (U.S. Senate 1936).

Changes in environmental conditions within a growing season can be observed by using the national index of pasture and rangeland condition (U.S. Department of Agriculture 1987) (fig. 18). Measured on the first of May, June, and August, this national index reflects the

seasonal variability in precipitation and temperature from 1969 to 1985. Good environmental conditions early in the year may deteriorate as precipitation decreases and temperature rises toward the end of the growing season, especially evident during August in 1974 and 1980 (fig. 18).

Environmental conditions vary not only year to year but also across the United States (fig. 19). The average 1975-84 pasture and rangeland condition was good to excellent in far western and northern parts of the United States, but conditions averaged only poor to fair in the northcentral and southern parts of the United States (U.S. Department of Agriculture 1987). These spatial patterns contrast with drought conditions in 1986 (fig. 19). In this year, poor to fair conditions occurred in parts of northeastern United States that averaged good to excellent over the previous 9 years. Excellent conditions favored the northern Great Plains which had averaged poor to fair over the previous 9 years. Below-average environmental conditions must be balanced by proper management to sustain the long-term productivity of these ecosystems.

The variability associated with weather, and consequently forage production, impacts land use. This relationship can be displayed by using the index of forage variability, which is the difference between the maximum and the minimum forage production in above and below average precipitation years, divided by the mean forage production (Sala et al. 1988). As the index approaches 1, fluctuations in forage production are as large as the average implying that forage production is highly variable. As the index approaches zero, production varies little from year to year. Within the Great Plains, the variability is greatest in the southwestern part



NOTE.--Numerical equivalent of condition: 80 and over, good to excellent; 65-79, poor to fair; 50-64, very poor; 35-49, severe drought; and under 35, extreme drought.

Source: USDA (1987)

Figure 18.—Average pasture and range drought condition, as measured May 1, June 1, and August 1 in the United States.

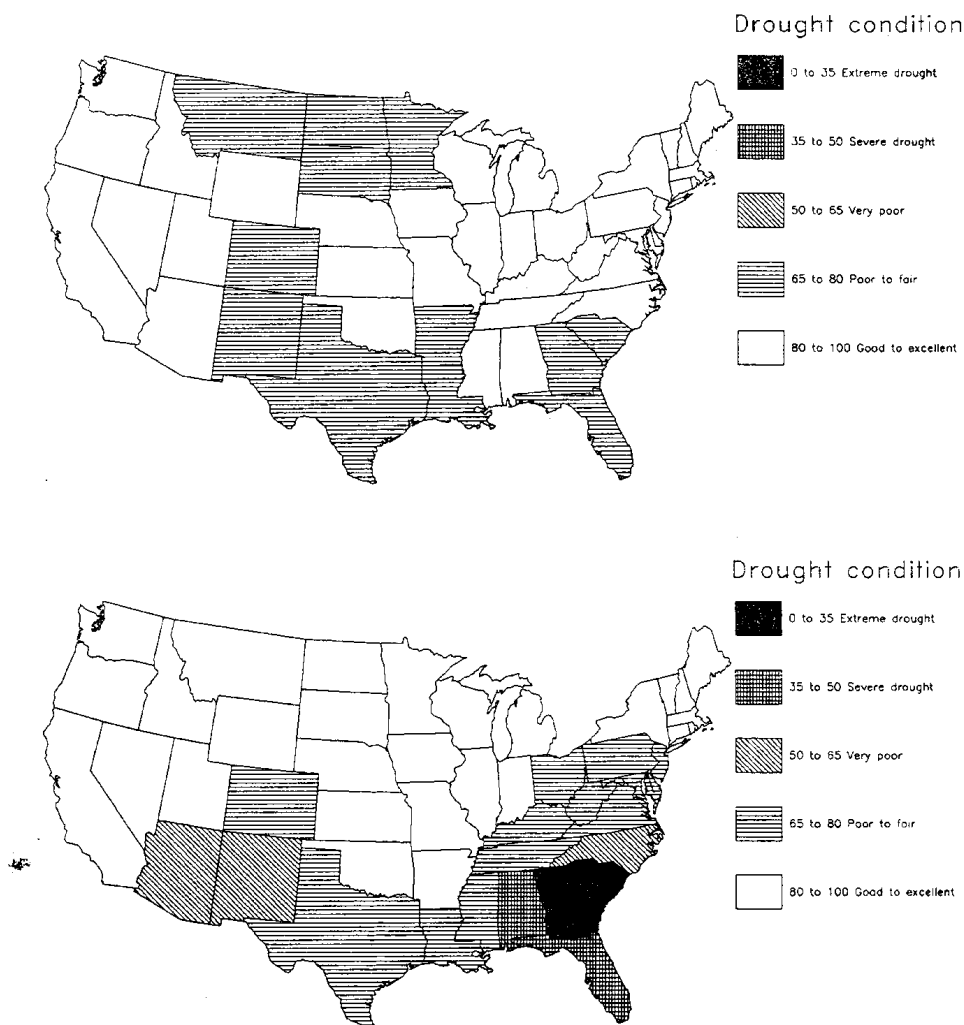


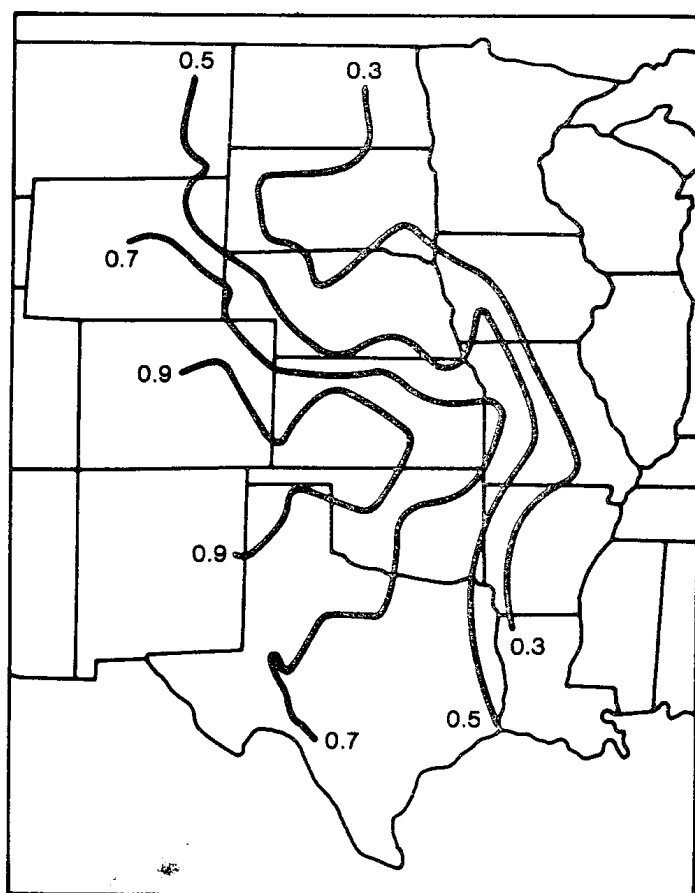
Figure 19.—Pasture and range drought condition, June 1.

of the region, in the corner of the Colorado, New Mexico, Oklahoma, and Texas state boundaries (fig. 20). Variability decreases as one moves further east and north. Annual precipitation also increases in this direction. The shape of the area where variability is higher than 90% coincides with Borchert's (1950) wedge of spring and summer rainfall deficiency, characteristic of major drought years across central United States. Borchert (1950) showed that during drought years, precipitation tended to decrease toward the center of this wedge-shaped area and be near or above normal outside the wedge.

This area of greatest variability in forage production also coincides with the largest acreage enrollment of the most recent government crop set-aside program, the Conservation Reserve Program, and with the largest acreage enrollment of the 1950s government program, the Soil Bank program (Reichenberger 1987). Crop production in the Great Plains is subject to the same environmental variability as forage production. The management of these lands, the government agricultural

programs, and the environment interact to influence changes in land use within this region and across the United States.

Although the results are unclear, evidence exists that the average air temperature will rise globally from 1 to 5° C because of past and current greenhouse gas emissions, such as carbon dioxide (U.S. Environmental Protection Agency 1988). These greenhouse gases absorb the earth's infrared radiation and warm the atmosphere. Future concentrations of these greenhouse gases based on forecasts of energy consumption, energy efficiency, and population growth are projected to double by the year 2030 (Mintzer 1987). Stringent energy conservation and efficiency would delay the doubling until 2075 (Mintzer 1987). The implication of this warming on the globe's climate is the focus of general circulation models, however, the resultant changes in local or regional climate are hard to forecast. Changes in climate will involve not only temperature changes, but also annual precipitation amounts and the seasonal distribution of this precipitation. For arid areas, the subtle shift



Source: after Sala and others (1988)

Figure 20.—Variability in forage production across the Great Plains as measured by the forage production index.

in increased variability of precipitation could potentially cause significant shortages in water for plants, animals and humans (Guldin in press, Waggoner 1988). These changes in climate could affect the current distribution of plants and animals, and the possibility exists for these climatic changes to occur more quickly than plants or animals could adapt (U.S. Environmental Protection Agency 1988). These changes imply the loss of plant and animal species, and the movement of plants into new ranges. These vegetation changes will imply shifts in land use, and economies dependent upon natural vegetation, such as rangeland, will be impacted by the potential future changes in climate. The projections for forage in this assessment are based on a future in which the climate follows historical trends. This assumption may not be met if the earth's climate changes rapidly. A number of studies have been initiated by the Forest Service (USDA Forest Service 1988a) and others (Committee on Earth Sciences 1989, Special Committee for the IBGP 1989) to examine the potential impacts of climate change.

Succession and Disturbance

Succession

The response of ecosystems to stress and disturbance is a function of the development and the past management of the ecosystem. Some of the different stresses under which ecosystems evolved include recurrent fire, grazing, no grazing by herbivores, periodic drought, high winds, and periodic flooding. As an ecosystem responds to repeated disturbances, soil, vegetation, and animal communities may follow a recovery path that is similar to the original path of ecosystem development. This response is particularly true if conditions are similar to those that existed when the ecosystem was developing (such as the periodicity of fire), and past use has not greatly altered one or more environmental factors (such as excessive erosion or introduced species). This path has been referred to as succession: the different plant and animal communities along this path are called successional stages (Cattellino et al. 1979, Drury and Nisbet 1973, MacMahon 1981, Odum 1971, Raynal and Bazzaz 1975, Shugart and West 1981). Major natural disturbances, steps in initiating revegetation after a disturbance, and the rate of recovery differ across ecosystems (MacMahon 1981). Different disturbances or stresses may induce an ecosystem to progress along different paths of recovery.

The management of ecosystems for multiple resource outputs requires an understanding of the individual ecosystem response to stress or disturbance. As different vegetation and animal species are present in each of the successional stages, the management for specific resource outputs may require managing for the stage that produces the desired output, and this successional stage may not be the PNC.

Natural Disturbance

Grazing animals have long been a part of forest and rangelands. Wild and domestic grazing animals influence primary production and other processes in the range ecosystem in a number of ways: defoliation of plants through eating and physical damage, digestive processes and the deposition of waste products, and movements such as bedding and trailing (Heady 1975, Pieper and Heitschmidt 1988). Defoliation from grazing has four aspects: (1) the intensity or degree to which a plant is defoliated, (2) the frequency or number of times a plant is grazed within a growing season, (3) the phenological stage of a plant when grazed, and (4) selectivity or the preference of the plant by the grazer or browser (fig. 17). These grazing influences imply management manipulations possible with grazers: adjust intensity, frequency, and seasonality of grazing, or change to a kind or class of animal with different diet preferences or grazing behavior (Heady 1975). Plant species consumed by cattle may or may not be the same plant species that deer, elk, goats, or sheep consume. Competition between grazing animals occurs when the dietary

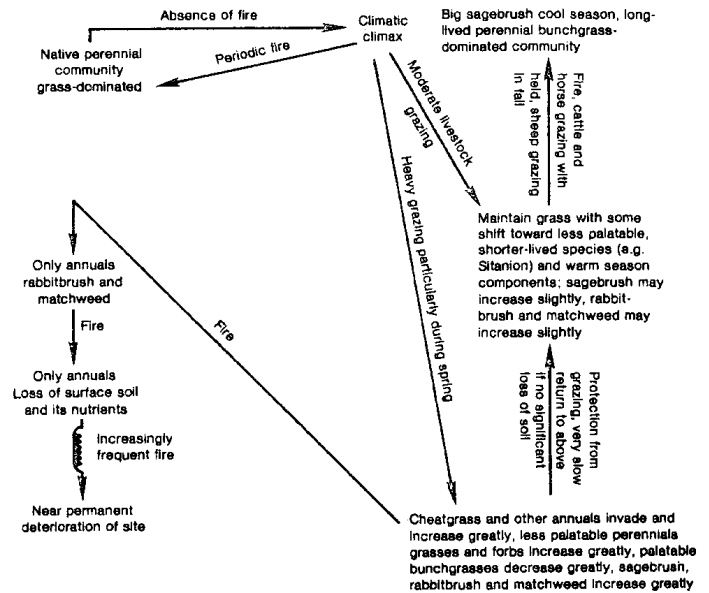
overlap is great, little forage is available, or large numbers of animals are grazing the same area. Thus, the impact of the grazing animal will depend on the type or types of animal using an area.

Periodic fire is a part of the natural disturbance regime of North American grasslands (Sims 1988b, Wright and Bailey 1982). Although the presettlement frequency of fire in the Great Plains cannot be determined precisely, Wright and Bailey (1982) concluded that on level to rolling prairie grasslands, the fire frequency may have been every 5 to 10 years. The suppression of fire in the eastern parts of the prairie ecosystem has led to the encroachment of trees and shrubs from the eastern deciduous forests. Periodic fire also reduces competitive advantage of cool-season invaders such as Kentucky bluegrass and smooth brome and improves the palatability and nutritional value of the grazable forage (Sims 1988b).

Management can disrupt a natural disturbance cycle and change the ecology of an ecosystem, as seen in the lowland sagebrush semi-desert ecosystem. When periodically disturbed by fire and in the absence of heavy grazing, this ecosystem moved towards a native perennial grass-dominated community (West 1983). When disturbed by moderate livestock grazing and fire, the community of perennial grasses contain additional less palatable, shorter-lived, species of grass and increased amounts of sagebrush (fig. 21). Heavy grazing pressure reduced the occurrence of perennial grasses, allowing the increase of brush and the invasion by annual grasses, particularly cheatgrass (Young et al. 1987). These annual grasses initiate and complete their growth and the production of many seeds during the short period of spring moisture. During the dry season, these annual grasses provide a fine-textured fuel for wildfires that spread from shrub to shrub (Young et al. 1987). Annual grasses can withstand fires better than the perennial grasses, thus, grazing and increased reoccurring fires favor annual grasses over perennial grasses. A declining spiral of productivity ensues, and annual grasses replace perennial grasses in this ecosystem (West 1983). Removing the grazing animals does not foster the return of the historical successional dynamics once annual grasses dominate (fig. 21).

Forest Succession

In forest ecosystems, the first vegetation to appear after timber harvest is grasses and forbs, followed by shrubs (Thomas 1979). This transitory range offers forage for wild and domestic herbivores. The length of these early successional stages varies by the physical and biotic characteristics of the site. In southern forests, the grass and forb stage lasts less than 10 years. In western United States, weather or soil factors may extend these stages to 20 to 40 years. Eventually, trees begin to colonize this previously forested site and reduce sunlight reaching the forest floor. Management activities can shift understory vegetation to an earlier or later successional stage depending on the current status (fig. 22). Shrub control with herbicides can facilitate tree growth by reducing



Source: after West (1983)

Figure 21.—Major pathways of succession in plant communities on lowland sagebrush semi-desert sites.

shrub competition, thus encouraging successional processes in forest ecosystems. Grazing in the grass-forb stage retards shrub and tree growth, thus retarding succession. The many types of herbivores will differentially impact species composition and succession (fig. 22). The timing of management applications, such as fertilization or controlled burn, influences the direction of change also (fig. 22). Timber management practices, such as thinning, open up the forest canopy, allowing sunlight to reach the forest floor, and increase grass and forb production.

On commercial forestlands, the biological environment is manipulated to intensively grow trees. Where environmental factors are not limiting vegetation growth, a possibility exists to maximize multiresource production on these sites. The introduction of pasture grasses under timber plantations and irregular spacing of trees can enhance the production of understory forage on these commercial forestlands (Lewis 1984). The introduction of grazers to reduce grass, forb, and shrub competition with trees can increase the diameter growth of small trees 8-14% (Mosher 1984). The multiple use management of timber plantations can have benefits in terms of increased profit, biological control of competing vegetation, and recreational benefits from wildlife (Pearson and Cutshall 1984).

Changes in the Resource Base

The historical and current management of forest and rangeland has changed the composition of plant and animal species in many ecosystems. Although livestock grazing has received much focus as a primary change agent, other uses have also affected forest and rangelands. All land in the United States now in cropland or

Management action							
Shrub control:							
• Herbicides	▶	▶	▶	◀	◀	◀	
• Mechanical control	◀	◀	NA	◀	◀	◀	
Controlled burn:							
• Cold burn	◀	◀	▶	▶	◀	◀	
• Hot burn	◀	◀	◀	◀	◀	◀	
Fertilization	◀	▶	▶	▶	▶	○	
Grazing and browsing (moderate rates):							
• Cattle and sheep	◀	▶	○	○	◀	◀	
• Goats	○	◀	○	○	◀	◀	
• Deer and elk	◀	▶	○	○	◀	◀	
Planting:							
• Trees	▶	▶	NA	NA	▶	▶	
• Shrubs	▶	◀	NA	NA	NA	NA	
• Grasses-forbs	▶	◀	NA	▶	▶	○	
Regeneration cut:							
• Clearcut	NA	NA	NA	◀	◀	◀	
• Shelterwood	NA	NA	NA	▶	◀	◀	
• Seed tree	NA	NA	NA	◀	◀	◀	
Salvage	NA	NA	◀	◀	◀	◀	
Thinning (including single tree selection harvest)	NA	▶	▶	▶	▶	○	
▶ advances succession ◀ retards succession ○ no effect on succession NA not applicable	Grass- forb	Shrub- seedling	Pole- sapling	Young	Mature	Old growth	
Successional stage condition							

Source: after Thomas (1979)

Figure 22.—Anticipated changes in successional stage resultant from management activities on forest land.

urban use was at one time forest or rangeland (fig. 8). Presettlement vegetation was probably near or at climax, with an occasional disturbance by natural catastrophe causing the vegetation to return to an early stage and succession (Wagner 1978). Settlers entered these ecosystems, removing the natural vegetation to make room for food crops, harvesting timber for fuel and shelter, and replacing wild herbivores with often too many domestic animals (Box 1978, Heady 1975, Rowley 1986). During 1880-1900, ecosystems in California were subjected to a combination of management stresses: severe overgrazing from high livestock numbers, the largest acreages plowed, the least informed forest practices, and the most extensive burning in the history of California (Heady 1975).

An overestimation of the productive capacity of semi-arid and arid lands resulted in many failed attempts to homestead on 160 acres in the Great Plains during the late 1800s. Abandoned farm fields in western areas can take nearly 50 years to develop natural vegetation similar to the surrounding rangelands (McGinnies 1983). The

more recent conversion of rangeland into cropland has been facilitated by technological developments, such as four-wheel drive tractors, electronically controlled harvesters, pesticides, fertilizers, and hybrid plant species. As a result of this new technology, the yield of wheat per inch of precipitation in the Great Plains has nearly tripled since 1930 (Lacey 1983 citing Sampson 1981). New arid land cropping technologies were given as a reason for the plowing of rangelands in the 1970s (Hendricks 1983).

Changes in riparian zones can be attributed to several factors including the number and distribution of natural and introduced large grazing animals, the alteration of flow caused by diversion of water for irrigation and reservoir storage, the multiple use of watersheds, and the present exploration for oil and gas (Skinner 1986). Erosion has been a part of the historical landscape, as large wildlife (bison) herds sought the use of water in these riparian zones (Skinner 1986). Past management activities such as channelization, water storage facilities, and vegetation clearing, in combination with livestock grazing, have resulted in a loss of 70% of the original area of riparian vegetation in the United States (Swift 1984). However, some land management activities created riparian zones where none previously existed (Skinner 1986). Cottonwood bottomlands in the northeastern Colorado were rare along the South Platte River, until large ranching operations began irrigation. The cottonwood population peaked during the 1950s but has declined since then primarily because of water management which has restricted overbank flooding (Crouch 1979).

Concern about the impacts associated with the severe overgrazing during the early 1900's (U.S. Senate 1936)—degraded rangeland, gully erosion, and loss of riparian habitat—led to management that has generally improved range condition since 1935 (Busby 1979). Recommended stocking rates and grazing systems were developed and implemented to efficiently utilize upland vegetation. These grazing systems often overutilized riparian vegetation, while maintaining the condition of rangeland as a whole (Platts 1986). Many Great Plains woody stands no longer exist in riparian areas and have been replaced by grasses and forbs. The deterioration and lack of reproduction within the remaining woody stands is attributed mostly to past heavy cattle use (Boldt et al. 1979). Along the lower Colorado River, Ohmart et al. (1977) estimated that the cottonwood community had declined from 5,000 acres in historical times to scattered groves containing a few mature individual trees. Livestock have impacted the riparian zones by trampling of the streambanks, causing loss of vegetation cover, lowering the water table, and making stream channels wider and shallower (Busby 1979, Kauffman and Krueger 1984, Platts 1979).

The introduction of exotic plant species either purposefully or accidentally has had and continues to have significant impact on the Nation's landscape. As invaders, exotic plant species can diminish forage production, but some planted exotics can enhance forage production as valuable forage, such as crested wheatgrass. In

Illinois, 811 species or 29% of the state's flora are naturalized from foreign countries (Harty 1986). Lehmanns lovegrass in Arizona and buffel grass in Texas, introduced as new forage species, have invaded native stands and now dominate certain areas. The accidental introduction of leafy spurge, about 100 years ago, now means an annual loss of \$20 to \$30 million in forage and beef production for western farmers and ranchers, including the costs of chemical control (Wood 1987). The plant species saltcedar, introduced as an ornamental, has successfully invaded riparian areas in western United States (Horton 1977). In this situation, two management activities facilitated the change in the landscape: the introduction of an exotic plant species, and the manipulation of the flooding regime in the riparian zone. At a larger scale, government crop reduction programs have facilitated the planting of valuable, but introduced, pasture species.

The accidental or purposeful introduction of animal species includes carp, nutria, house mouse, Norway rat, European wild boar, European starling, rock dove, balsam wooly aphid, and gypsy moth (Harty 1986). Large grazing animals from other parts of the world, such as kudu and impala, are now part of many game ranches in western United States (U.S. Congress, Office of Technology Assessment 1986a). These animals provide income to ranchers, genetic reserves for threatened and endangered species, and recreational opportunities.

Brush invasion is the encroachment of undesirable perennial woody plants in ecosystems in which these shrubs are not part of the climax plant community, or the increase in shrub density where the natural density is low (USDA Soil Conservation Service 1987c). Shrubs species most common in this category include mesquite, juniper, sagebrush, several species of oak, saw-palmetto, creosote bush, and chaparral shrubs. Under dense shrub production, grass and forb production is lessened and soil erosion increases (USDA Soil Conservation Service 1987c). Invasion by shrub species has had negative impacts on habitat for wildlife species such as bighorn sheep, pronghorn, sage grouse, masked bobwhite quail, and northern aplomado falcon. Shrub invasion has had positive impacts on habitat for some wildlife species, such as mule deer (Flather and Hoekstra in press). Brush management could enhance forage production on almost 81 million acres of nonfederal rangeland. On over 17 million acres of nonfederal rangeland, brush control and the reestablishment of desirable forage plants by seeding is considered necessary to reestablish a productive rangeland ecosystem (USDA Soil Conservation Service 1987c).

VEGETATION MANAGEMENT

Existing Technologies

Resource managers manipulate the processes of energy flow and nutrient cycling in order to obtain the production of forage for livestock and wildlife and sufficient plant cover to protect the soil from wind and water

erosion (figs. 17 and 22). Management decisions involve determining the suitability of the vegetation for different uses, designing and implementing range improvement practices, and manipulating the distribution, intensity, and seasonality of grazing by wild and domestic herbivores. Range improvements include special treatments, developments, and structures that can improve range forage quality or quantity or facilitate the efficient use of forage by grazing animals (Vallentine 1980).

The analysis of forage production to produce a specific output such as livestock or wildlife on an individual enterprise requires an analysis of the production system within which forage is an input (Workman 1986). The analysis of forage production requires a recognition of interrelations among the forage itself, the animal that grazes or consumes it, the soil/land resource, and the enterprise that must plan for economic survival (Tyner and Purcell 1985). This analysis reflects site-specific concerns such as the tradeoff between range improvement practices and the expected return in domestic or wildlife production. The successful implementation of these improvement practices must sufficiently increase the final output that is marketed from the enterprise before the practice is cost effective.

Practices that have been used to improve the management of rangelands may be broadly grouped: promoting desired plant species; controlling undesirable plant species, manipulating the distribution, intensity, and seasonality of grazing by wild and domestic herbivores; and controlling undesirable animal species (Vallentine 1980; U. S. Congress, Office of Technology Assessment 1981). Technology to enhance the production of herbivores is discussed in Chapter 3. Technology to enhance vegetation production includes capital intensive techniques for shrub removal or less intensive practices such as fire (table 11). Reseeding and interseeding practices have been used to replace or enhance the composition of desirable forage species when the native vegetation is of poor quality or lacking in quantity. For example, winter ranges of mule deer and domestic sheep can be enhanced by plantings or seedings of the recently released 'Hobble Creek' low-elevation mountain big sagebrush (Welch et al. 1986).

Lands that have undesirable species can be controlled by a number of mechanical, chemical, and biological methods, but success rates vary with environmental conditions and application. Mechanical plant control has included crushing, uplifting or knocking down plants, and plowing the root zone of undesired vegetation (table 11) (Vallentine 1980). The use of fire in controlling undesirable plant species has the advantages of being inexpensive and effective against non-sprouting species. Until the late 1940s and early 1950s, chemical control was limited to individual-plant treatments because most herbicides were not highly selective (Scifres 1977). Since then, the number of chemicals and control methods has increased (table 11). Aerial spraying of chemicals is particularly advantageous for rangelands with difficult terrain. The future development of chemicals that are highly specific in their effect is important to selectively manage for desired species. Biological control which is

Table 11.—Status of development and application of facilities and equipment used to manipulate vegetation for managing and improving range ecosystems of the Great Plains.

Facility or equipment item ¹	Status of development ²	Extent of application ³
A. Mechanical plant control		
1. Plant root extraction by plows or grubbers	3	2
2. Brush clearing by rakes, chains or rails	3	2
3. Choppers and shredders	3	2
4. Mowers	3	3
5. Handtools	3	3
B. Herbicide application		
1. Fixed-wing or helicopter sprayers	3	2
2. Vehicle mounted boom sprayers	3	2
3. Other vehicle mounted applicators	2,3	2
4. Mist sprayers	3	2
5. Subsoil injectors	3	1
6. Tree injectors	3	2
C. Seeding		
1. Broadcast seeders		
a. Fixed wing or helicopter spreaders	3	2
b. Seed dribblers	3	3
c. Blower or rotary spreaders	3	3
d. Steep slope scarifier seeder	3	1
e. Hydraulic seeder-mulchers	3	2
f. Grass seeder (spreader with cultipacker)	3	2
2. Drills		
a. Grain drills	3	3
b. Heavy-duty grain drills (pasture drills)	3	2
c. Rangeland drills	3	2
d. Presswheel drills	3	2
e. Seeder for brush littered range	2	1
3. Interseeders		
a. Range interseeders	3	2
b. Tiller seeders	3	1
c. Interseeder for rocky and brushy areas	3	2
4. Others		
a. Sodders or spriggers	2	1
b. Tree and shrub planters	3	1
D. Fire management		
1. Ignition devices	3	2
2. Fireline plows	3	2

¹Equipment and facilities are grouped according to their principal use. Many have a variety of applications.

²Status of development:

1 = Undeveloped.

2 = Various stages of development, not available for general use.

3 = Fully developed and available for use; refinements may be made in existing equipment.

³Extent of optimum application:

1 = None or very limited

2 = Significant, but incomplete

3 = Complete or near complete

Source: After Lewis and Engle (1982).

the study, importation, augmentation, and conservation of natural enemies (Dahlsten 1986), can be very successful against exotic plant species. One of the earliest successes occurred in the mid-1940s when *Chrysolina* beetles were introduced into northern California to control St. Johnswort. By 1958, St. Johnswort had been reduced

to less than 1% of its former abundance (Vallentine 1980). The use of grazing animals such as livestock to control weedy species is a promising area of research.

Integrated pest management (IPM) is the selection of two or more compatible pest suppression tactics for control of a single pest organism: animal, plant, insect, or

pathogen pest (Johnson 1987). Although IPM offers potential treatments for rangeland pests, managers are confronted with problems concerning the various costs and benefits of individual pest management options for rangelands. Data on the economic thresholds for selecting control methods for nearly all pests are absent (Capinera 1987). When control methods are examined for animals such as prairie dogs which have long been considered pests, research suggests that the animals may not be economical to control and are important in the enhancement of wildlife diversity and for sport hunting (Uresk 1987).

Although many technologies currently are fully developed and available for use, the extent of their implementation is often lacking (Lewis and Engle 1982). Within the Great Plains, the only mechanical plant control methods considered to be nearly complete in optimum application are mowers and handtools (table 11). Heavy equipment has been applied but not as extensively. Seeding equipment developed for steep slopes or brush-littered rangelands is less likely to be implemented than other seeding technologies for more accessible rangeland. The extent of technological application appears poor for capital-expensive treatments (heavy equipment) and for technologies for areas of likely low return (steep slopes or woody rangelands). An evaluation of improvement practices within the depressed livestock market of the last few years has not suggested the profitable implementation of many range improvement practices (Pope and Wagstaff 1987b).

Future Technologies

The future productivity of agriculture and livestock could potentially be increased by the development and implementation of 150 existing and potential technologies (U.S. Congress, Office of Technology Assessment 1986b). These technologies span improvements in plants such as genetic engineering, plant physiology, improvements in disease and pest management, and monitoring of the environment and labor-saving technologies (table 12). The future availability of such technology was based on a real rate of growth in research and extension expenditures of 2% per year, and the continuation of all other forces that have shaped past development and adoption of technology (U.S. Congress, Office of Technology Assessment 1986b). Decreases or increases in research and extension expenditures shift the future availability of these technologies (table 12). Technologies developed for croplands that can easily be implemented on rangelands and technologies developed for grain crops will impact forage production earliest. Environmental monitoring devices, communications and information management, and telecommunication devices are available today. Computer software and database systems can handle large amounts of data and aid in farm/ranch management decision analyses. Developments in this information management technology will enhance research and development in forest and rangeland management (Wisniol and Hesketh 1987).

Technologies to improve disease resistance, weed control, and the management of insects and mites were also

forecast to be available before 2000 (table 12). The enhancement of photosynthetic efficiency and plant growth regulators were also available by 2000. Understanding drought resistance and tolerance, and improving water use efficiency through recombinant DNA were not forecast as being available until 2000. Plant technologies were seen as lagging behind animal technologies, and significant improvement in primary production would not occur until the year 2000 (U.S. Congress, Office of Technology and Assessment 1986b). Animal technologies will affect the production of livestock and the consequent demand for forage (Chapter 3).

The potential impact of these technologies on range plant production involves economic and social factors. The Soil Conservation Service (SCS) reported that an economic analysis of the range livestock industry showed that rangeland is more responsive to intensive management practices than to capital-intensive practices (USDA Soil Conservation Service 1987c). Much of the technology identified in table 12 is capital-intensive; however, few range improvement practices have proved profitable in the recent livestock market.

The extent that technology could improve forage production is viewed as highly significant in many parts of the United States. The application of existing technology could potentially increase forage production 100% to 200% in Southwestern ecosystems (Dwyer 1982). Similar estimates of potential improvement in range forage production were made for the Pacific Northwest grazinglands by Box (1982). In contrast, significant improvements in forage production in the Northern (NO) region will depend on the development of technologies to produce multiple resources from forested lands (Byington 1982).

AVAILABILITY OF GRAZINGLAND

Past Legislation and Land Use

Legislation has affected the management of lands in private and public ownership (table 13) and thus, indirectly, the supply of forage nationally. The early homestead acts (1862, 1873, 1877) transferred public domain land to private individuals under certain management conditions (Smith 1979). Government cropland control programs can influence the acreage of land available for forage production. This influence was evident in the Soil Bank (1956) that allowed grazing and the Conservation Reserve Program (CRP) (1985) that did not allow grazing.

Grazing on public lands was important in the start of the livestock industry in western United States (Blaisdell and Sharp 1974, Rowley 1986). The use of federal lands for grazing was first regulated on forest preserves in 1897, and on public domain lands in 1934 (table 13). The poor condition of the federal lands before this time has been discussed by a number of authors (Blaisdell and Sharp 1974, Box 1978, Rowley 1986, Stoddart et al. 1975). This regulation of grazing on federal lands helped to control excessive grazing (Rowley 1986). Legislation

Table 12.—Emerging technologies for plant production and likely year of introduction under three future environments for technological development.

Technology	Technology environments		
	More new technology ¹	Most likely ²	Less new technology ³
Genetic engineering:			
Microbial inoculums	1990	1990	Never
Plant propagation	1983–90	1983–90	> 1990
Genetically engineered cereals	1995	2000	2010
Enhancement of photosynthetic efficiency:			
Basic process of photosynthesis	1983	1983	1983
Photosynthetic control	1983–90	1983–90	1983–2000
Photosynthetic molecular biology and genetics	1990–2000	1990–2000	1990–2000
Mechanisms of response and adaptation to stress	1990	1983–95	2000
Plant growth regulators:			
Controlling growth/development	1984	1984	1985
Disease and insect resistance	1986	1988	1990
Overcoming environmental stresses	1986	1988	1990
Plant disease and nematode control:			
Breed cultivators	1984	1984	1984
Genetic engineering	2000	2000	2025
Bacteriocides, fungicides, and nematocides	1988	1990	2000
Biocontrol agents	1985	1990	2010
Management of insects and mites:			
Chemical controls	> 1995	2000	> 2000
Genetic engineering			
Pathogenic chemicals	1995	2000	2005
Plants	2000	2005	2010
Information processing	1984	1984	1984
Weed control:			
Bioregulation through chemical and biological technology	1984–2000	1984–2000	1984–2000
Allelopathic chemicals	1990	1995	2000
Crop tolerance and susceptibility to control agents	1992	1998	> 2000
Biological nitrogen fixation:			
Improved strains of rhizobia	1984	1984	1984
Stress-tolerant rhizobia	1987	1990–95	1995–2000
Legumes more active in nitrogen fixation (plant breeding)	1990–95	1990–95	1990–95
Nitrogen-fixing cereals	> 2000	> 2000	> 2000
Chemical fertilizers:			
Increasing efficiency of nitrogen use	1990	1995	2000
Decreasing energy required	1980	1980	1980
Processing of lower quality phosphate rock into fertilizers	1990	1990	1990
Ammonia from coal	1995	2000	2000
Communications and information management:			
Communication networks, data terminals, software	1985	1985	1985
Manufacturing management systems	1987	1990	2000
Expert systems	1990	1992	1997
Monitoring and control:			
Sensors, controllers, displays	1984	1984	1984
Water and soil-water-plant relations:			
Understanding drought resistance/tolerance	2000	2020	2050
Plant breeding	1984	1984	1984
Biotechnology:			
Water use efficiency	2010	2030	2050
Water management	1984	1984	1984
Photovoltaic systems	1995	1995	2010

Table 12.—Continued

Technology	Technology environments		
	More new technology ¹	Most likely ²	Less new technology ³
Soil erosion, productivity, and tillage:			
Conservation farming systems	1995	1995	1995
Assessing erosion and its impact	1995	1995	2000
Reclaiming lands	1995	1995	> 2000
Organic farming:			
Biocides	1984	1984	1984
Reduced soil erosion	1984	1984	1984
Self-sufficiency for nutrients	1984	1984	1984
Minimum tillage with minimal biocide use	1990	1990-95	2000
Rotations			
Use	1984	1984	1984
Knowledge	1990	1990-95	2000
Labor-saving technologies:			
Robotic farming of grains	1995	2000	2010
Crop separation, cleaning, and processing:			
New methods for separating and cleaning grain	1995	1995	1995
Infield or onfarm processing:			
Forage	1990	1990	2000
Oilseed	1984	1984	1984
Engine and fuels:			
Adiabatic compression ignition engines with turbocompounding	1990	1990	1990
Electronic engine controls	1985-86	1986	1986
Alternative fuels			
Grains	1984	1984	1984
Cellulose	1995	2000	2010
Land management:			
Conservation tillage	1984	1984	1984
Controlled traffic farming	1987	1990	1995
Customized-prescribed tillage	2000	2005	2020
Multicropping	1984	1984	1984
Telecommunications:			
Digital communication	1995	2000	2010
Fiber optics	1990	2000	2010
Personal computers	1985	1985	1985
Videotex and teletext	1985	1985	1985
Value-added networks	1985	1985	1985
Integrated services digital network	1990	1990	> 2000
Remote sensing	1985	1985	1985

¹Assumes to year 2000: (1) a real growth rate in research and extension expenditures of 4%, and (2) all other factors more favorable than those of the most likely environment.

²Assumes to year 2000: (1) a real rate of growth in research and extension expenditures of 2%, and (2) the continuation of all other forces that have shaped past development and adoption of technology.

³Assumes to year 2000: (1) no real rate of growth in research and extension expenditures, and (2) all other factors less favorable than those of the most likely environment.

Source: After U.S. Congress, Office of Technology Assessment (1986b).

has continued to affect the management of federal lands (table 13). Recent legislation has emphasized the multiple use of federal lands (1960), the need to examine potential impacts of management (1969), the management of wild horses and burros as part of Forest Service (FS) and Bureau of Land Management (BLM) grazing management (1971), the decadal assessment of current

and future production of natural resources on all forest and rangelands with the development of a national program for FS (1974), and the need for a planning process on all National Forest System (NFS) lands and all BLM-administered lands (1976). These factors affect the supply of forage as it is allocated to each of these uses on federal lands.

Table 13.—Legislation affecting the management of forest and rangelands in the United States.

Year	Law	Consequences
1862	Homestead Act	Encouraged settlement of West.
1873	Timber Culture Act	Settlement of 160 acre if trees planted.
1877	Desert Land Act	Land sold for 25 cents per acre if irrigated and cultivated for 3 years.
1897	Organic Administration Act	Regulated use of Forest Preserves (est. 1891)
1905	Transfer Act	Forest reserves transferred from USDI to USDA; created the Forest Service.
1906	Meat Inspection Act	Governed the slaughtering, packaging, and handling of meat shipped intrastate.
1916	Federal Farm Loan Act	Farmland banks created.
1920	Mineral Leasing Act	Allowed the Government to lease national forest lands for mining.
1924		Gila Wilderness, NM, became first official wilderness in NFS.
1928	Wool Standards Act	Appropriated funds for wool standards.
1928	McSweeney-McNary Act	Established a program of forest research.
1934	Taylor Grazing Act	Designated grazing on public domain lands to be regulated by the BLM.
1950	Cooperative Forest Management Act	Federal cooperation with states to provide technical services to private forest landowners.
1952	Independent Agencies Appropriation ACT	User fees must be self-sustaining, uniform, fair and equitable to public and user.
1954		National Grasslands added to Forest Service
1956	Agricultural Act	Financial assistance to farmers converting cropland to conservation uses (Soil Bank).
1960	Multiple-Use and Sustained Yield Act	National forest management to recognize multiple resources and uses.
1964	Wilderness Act	Creates National Wilderness Preservation System.
1964	Trade Agreement	US-Australia agreement limits Australian export of beef, veal, and mutton.
1964	Tariff Act of 1930 Amendment	Allowed the free importation of certain wild animals and imposed quotas on certain meat and meat products.
1969	National Environmental Policy Act	Analyses required for all management potentially affecting the environment.
1971	Wild Free-Roaming Horse and Burro Act	Management of wild horses and burros on FS and BLM lands now the responsibility of FS and BLM.
1973	Endangered Species Act	Federal management must not jeopardize the existence of endangered plant or animal species.
1974	Forest and Rangeland Renewable Resource Planning Act	Assessment of current and future production of natural resources on all forest and rangelands and development of a national program.
1974	Federal Noxious Weed Act	Provide for control of noxious weeds.
1976	Federal Land Policy and Management Act	Requires planning on BLM lands.
1976	National Forest Management Act	Requires planning process on all NFS lands.
1976	Beef Research and Information Act	Establish a program of research, information, and promotion for beef cattle and beef products.
1978	Public Rangelands Improvement Act	Grazing fee formula for FS and BLM, and requires analysis of fee in 7 years.
1978	Forest and Rangeland Renewable Resources Research Act	Authorized USDA research to be conducted on renewable resources.
1985	Food Security Act	CRP, sodbuster, swampbuster, conservation compliance.

Source: Smith (1979); USDA Forest Service (1983b); USDA Forest Service, and USDI Bureau of Land Management (1986).

Land Use at the National Level

Land Use Inventories

A series of land use inventories based on available statistics has been summarized by the Economic Research Service and its predecessor agencies (Frey 1973, 1979, 1982; Frey and Hexem 1985; Frey et al. 1968; Wooten and Anderson 1957; Wooten et al. 1962). Categories and area coverage have been generally comparable since 1945. This compilation of land use data from public agencies such as FS, Bureau of Census, BLM, and SCS provides a useful framework within which changes in the supply and demand for land can be analyzed (Frey and Hexem 1985).

Major land uses include forest land, cropland, and pasture and rangeland. The interpretation of these land-use trends is based on land use, not land cover. In this historical data, land with tree cover that is designated as wilderness is removed from the forest land category. Thus, data for the major land use categories of forest land, and pasture and rangeland do not include military lands, national parks, or wilderness area. These land-use inventories do not separate pasture from rangeland, thus long-term trends are available only for this combination. Historical records are also kept on special-use areas, such as roads, railroad rights-of-way, airports, federal and state parks, wilderness areas, wildlife refuges, defense, and industrial areas.

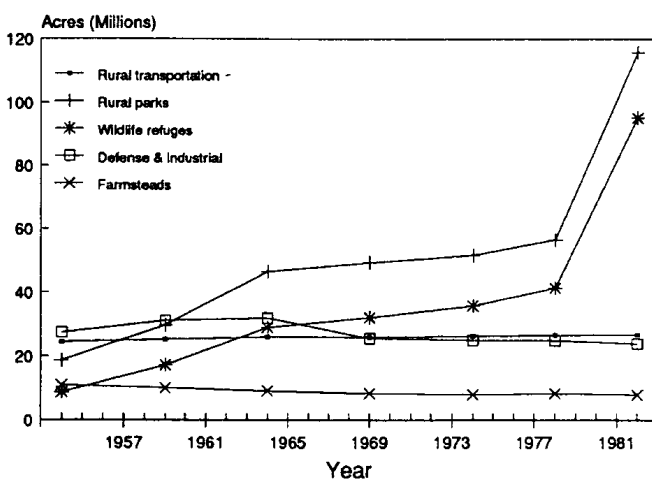
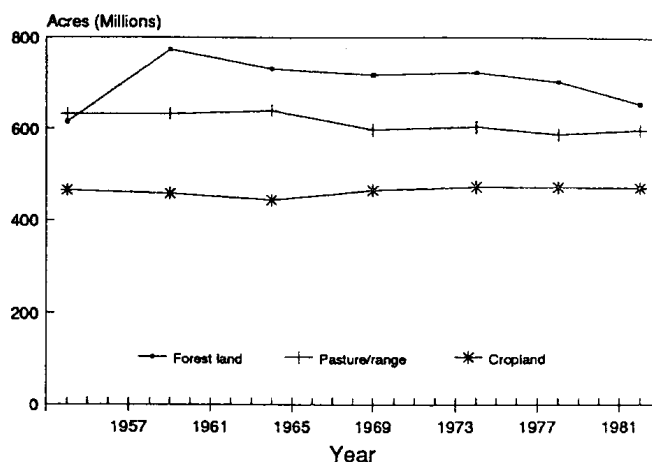
Major Land Use Trends

Since 1954, shifts in major land uses have been minor at the national level (fig. 23). The increase in forest land between 1954 and 1958 is the result of the inclusion of Alaska's lands with the U.S. land base. Since 1958, forest land conversions to land uses such as crop, pasture, and urban has resulted in a decrease in forest area. The legislated conversion of forest land into wilderness contributes to the decline in forest area and the increase in rural parks and wildlife refuges (fig. 23). Total cropland has remained fairly constant at around 450 million acres. Pasture and rangeland together form the second largest use of land in the United States. Acres in this land use category show a decline of 4% over this period, because this land has been converted to other uses such as agriculture or urban.

The most rapid land use change has been in the rural parks and wildlife refuges (fig. 23). This increase is associated with the Wilderness Act of 1964 (table 13) and greater interest in recreation and wildlife (Cordell in press, Flather and Hoekstra in press). In 1982, national and state parks and related areas totaled 116 million acres, and federal and state wildlife agencies administered an additional 95 million acres.

Trends in the Availability of Grazingland

The Nation's grazingland base includes forest land, rangeland, pasture, and cropland used for pasture.



NOTE.--Data from periodic inventories. Most recent inventory: 1982.

Source: Frey (1973, 1979, 1982), Frey and Hexem (1985), Frey et al. (1968), Wooten and Anderson (1957), Wooten et al. (1962)

Figure 23.—Major uses of land in the United States, 1954-1982.

Changes in this base⁴ have been estimated over time (Frey and Hexem 1985). Grazing available on forest land is estimated from the area in open forests, arid woodlands, and lands reverting to forest which have forage. Changes in nonforested pasture and rangeland include cropland pasture. Frey and Hexem (1985) reported that between 1969 and 1982, grazingland had declined 8%. Declines were steady in both forest grazing and nonforested pasture and rangeland.⁵

⁴These estimates exclude land on which grazing occurred before or after crops were harvested, and areas totaling about 60 million acres in federal grazing districts and range allotments that have little value for grazing but which are intermingled and managed with productive federal range. In addition, these estimates do not include special land uses such as wilderness or wildlife refuges.

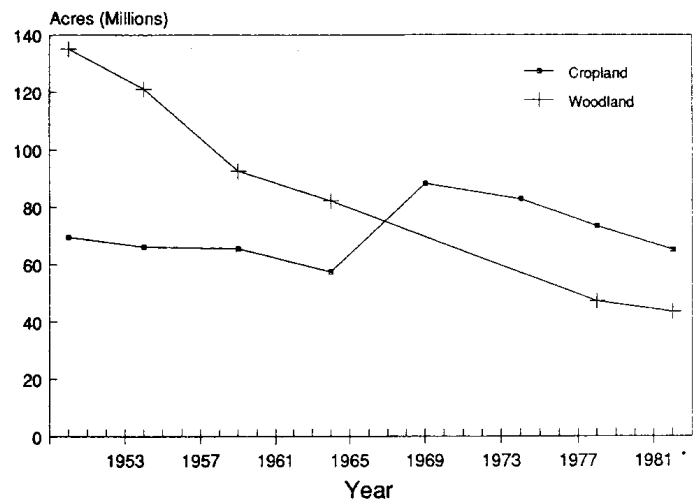
⁵Nonforested pasture and rangeland in this historical time series include cropland used for pasture as well as pasture and rangeland.

Several forces combine to cause the long-term decline in pasture and rangeland: (1) fluctuating demands for crop products shift acres between cropland and other uses such as pasture and rangeland, particularly in the South; (2) withdrawal of land for recreational, wildlife, and environmental purposes, particularly in the western United States; and (3) withdrawal of land for urban areas across the Nation (Frey and Hexem 1985). Since 1949, 41 million acres of pasture and rangeland have been converted to other uses. Since 1969, this decline appears steeper because 30 million acres have been converted to other uses in only 13 years. Although these estimates reflect some inconsistencies in classification and measurement, Frey and Hexem (1985) maintained that a long-term decline has occurred in pasture and rangeland, and that the 30 million acres converted to other uses since 1969 was more representative of the long-term rate of decline. This decline represents an annual loss of 0.33% in total nonforested pasture and rangeland.⁶

Cropland used for pasture, one component of pasture and rangeland area, fluctuated from a record low of 57 million acres in 1964 to a record high of 88 million acres in 1969 (fig. 24). These fluctuations correspond with government set-aside programs for crop surpluses. Cropland used for pasture represents a small total acreage when compared with the pasture and rangeland total, 65 million compared with the 598 million acres reported by Frey and Hexem (1985) for 1982. This cropland, however, is a highly productive component and represents the only available grazingland in some areas in certain seasons. The sensitivity of this grazing resource to conversion to crop production varies with the region. Cropland pasture makes up a proportionally larger amount of land in fertile agricultural areas such as the Corn Belt (Iowa, Illinois, Indiana, Ohio, and Missouri). In other areas such as the Appalachian region, cropland pasture is associated with small, irregularly shaped, and scattered fields not as likely to be converted to crop production (Frey and Hexem 1985).

Forest grazing by livestock has declined 50% since 1949. Although these estimates do not include special land uses such as wilderness or wildlife refuges, this decline in forest grazing does include changes in forest species such as improved commercial timber stock, increases in stand density, and improvements in livestock feeding and forest management practices (Frey and Hexem 1985). Areas designated as wilderness on NFS lands are grazed by wildlife and, if previously permitted, livestock. Thus, the historical forest grazing acreages

⁶Frey and Hexem (1985) reported 890 million acres in 1969 and 820 million acres in 1982 of grazingland—forest, pasture, and range. This 70 million acres loss represents an annual loss of 0.6% per year, or 5.3 million acres per year from the grazingland base. When only pasture and rangeland acres are examined, 692 million acres in 1969 and 662 million in 1982, the annual loss is 0.33% or 2.3 million acres per year. When the declines in forest grazing are included with pasture and rangeland, the annual decline in grazingland area would represent a total decline of 53 million acres in the grazingland base over 10 years. Forest grazing, however, has declined for a number of reasons, including changing management practices which exclude livestock grazing. Thus, while the CRP land will return acres to forest land, changes in management on forest land could impact forest grazing much more significantly.



NOTE.—Data based on periodic inventories. Most recent inventory: 1982.

Source: USDC, Census of Agriculture (1984)

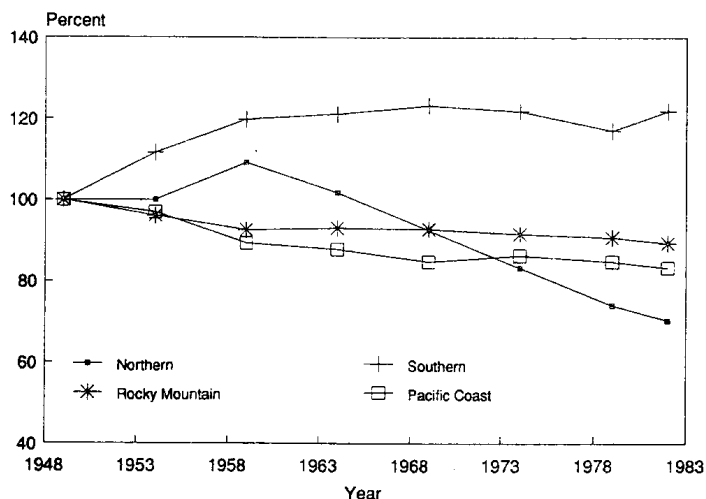
Figure 24.—Area of woodland pasture and cropland used only for pasture or grazing in the United States, 1950-1982.

probably underestimate forest land available for grazing. The total amount of woodland pasture on farms has declined from nearly 140 million acres in 1950 to less than 50 million in 1982 (fig. 24), based on the Census of Agriculture statistics (USDC Bureau of Census 1984). Thus, the woodland available for grazing on farms has dramatically declined since 1950. As a percent of total woodland, the amount grazed has remained around 50% (USDC Bureau of Census 1984).

Regional Trends in Pasture and Rangeland Use

Conversions of pasture and rangeland varied regionally across the United States in 1949-82 (fig. 25). Conversions of pasture and rangeland to other land uses were greatest in the NO and PC regions with a 30% and 17% decline respectively, relative to 1949 acreage. These regions had the fewest acres of pasture and rangeland. The increase of pasture and rangeland in the SO region reflected a substantial reclassification of noncommercial forest to open rangeland in Oklahoma and Texas, a decline in cropland used for crops with the associated increase in cropland used for pasture, and the clearing of commercial forest land, particularly in South Carolina, Georgia, Florida, Alabama, Oklahoma, and Texas. This increase in the South was not large enough to compensate at the national level for decreases in other regions, notably in the Rocky Mountain region where areas were withdrawn for parks, wilderness, or reclassified as unsuitable for grazing (Frey and Hexem 1985).

Increased conversions of rangeland during the late 1970s were related to a variety of factors: (1) a depressed cattle industry contrasted with a profitable wheat sector encouraged the diversification of ranching operations to include wheat production (Wight et al. 1983, Young



NOTE.—Data based on periodic inventories. Most recent inventory: 1982.

Source: Frey and Hexem (1985)

Figure 25.—Trends in pasture and rangeland area, relative to 1949, by assessment regions in the United States.

1984); (2) cash-flow problems encouraged ranchers to sell all or part of their land (Huszar and Young 1984); (3) increased credit availability on cropland as opposed to rangeland, and pressures from lending institutions to convert rangeland to cropland (Huszar and Young 1984, Young 1984); (4) price differentials in the market price of rangeland and cropland (Roath 1983, Watts et al. 1983); (5) incentives from government farm programs and income tax provisions that enhance the profitability of conversions (Heimlich 1985, Watts et al. 1983); (6) new technological improvements suggesting that semi-arid lands could be profitably cropped (Hendricks 1983); and (7) imperfect knowledge about climatic conditions in the arid regions suggesting to prospective buyers a possibility for farming (Laycock 1983).

Based on Frey and Hexem (1985), annual conversions of pasture and rangeland to other uses for 1969-82 period were:

Region	Annual Conversion million acres/year
Pacific Coast	0.08
Southern	0.15
Northern	0.92
Rocky Mountain	1.20

These annual rates can vary considerably with fluctuations in the demand for land for crop production. Schenarts (1981) reported that 31.9 million acres of pasture and rangeland alone were converted to cropland during 1967-75. Conversions of cropland to other uses, such as urban, exceeded the conversions into cropland over this period and the Nation's total cropland acreage decreased. The annual conversion of pasture and rangeland to cropland during 1967-75 was 0.2 million acres for the Pacific Coast region (2.5 times the 1969-82 rate),

Table 14.—Rangeland plowed in the northern and central Great Plains States.

State	Acres plowed	Time period	Source
Colorado	572,000	1978-83	SCS
Kansas	15,000	1978-83	SCS
Montana	762,000	1970-83	Montana ACD ¹
Nebraska	400,000	1978-83	SCS
North Dakota	849,000	1967-83	SCS
South Dakota	759,000	1974-82	SCS
Wyoming	33,000	1977-83	SCS (Laramie Co.)

¹Montana Association of Conservation Districts, available from 22 of 59 Soil Conservation Districts and do not include Phillips, Custer, and Garfield districts where plowing occurred in 1982-83.

Source: Laycock (1983).

1.2 million acres for the Southern region (8 times the 1969-82 rate), 1.1 million acres for the Northern region (1.2 times the 1969-82 rate), and 1.4 million acres for the Rocky Mountain region (1.2 times the 1969-82 period).⁷ The conversion of pasture and rangeland to urban land use and the return of cropland to pasture and rangeland are not included in these conversion rates. These higher conversion rates indicate a greater loss of pasture and rangeland when cropland demand is high, as it was during 1967-75.

Concern about the recent plowing of fragile rangelands has provided several additional estimates of the historical rangeland conversion to cropland in the Great Plains. Laycock (1983) presented estimates of grassland acres plowed in the northern and central Great Plains (table 14). For the seven states represented, an estimated 0.41 million acres of rangeland were converted to cropland annually in 1967-83 (table 14). Again, this represents rangeland plowed only for conversion to cropland. Frey (1983) reported that historic levels of land cropped in the Great Plains were greater than cropland currently in production, 132.5 million acres versus the 91 million acres in 1978. Cropping was extensive in most Great Plains counties in 1919-29 and 1944-54. Frey (1983) suggested that if acreage control programs had not been in effect, more counties would have had record acres in crop production during the 1970s. Thus, the conversion of rangeland to cropland has been high during periods of high crop demand, and in some local areas, the rate of conversion is quite high (table 14). Heimlich (1985) reported that conversions of pasture and rangeland during 1975-81 accounted for between 64% and 84% of new cropland in all regions of the United States. Thus, range and pasture serve as a reservoir for new cropland in all parts of the country.

⁷Conversion of pasture and range to cropland during 1967-75 totaled 1.7 million acres for the PC region, 10.0 million acres for the SO region, 8.6 million acres for the NO region, and 11.6 million acres for the RM region. For this 8 year period, annual conversion rates are 0.2 million acres, 1.2 million acres, 1.1 million, and 1.4 million acres, respectively.

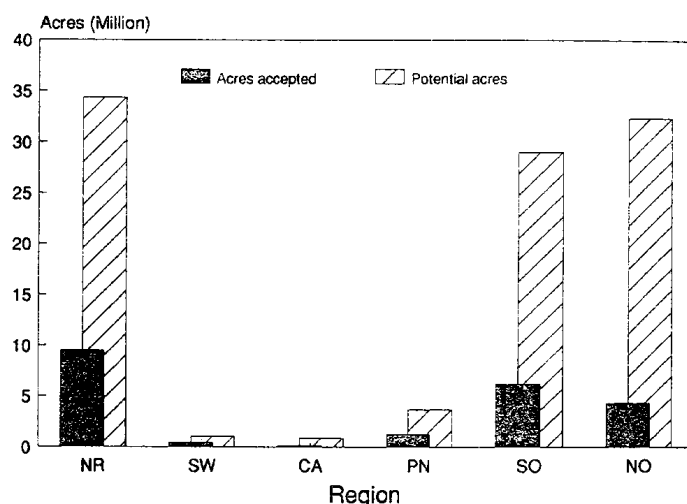
Government Agricultural Programs and Land Use Shifts

Programs designed to reduce crop surpluses have been short-term where cropland was enrolled annually and long-term where cropland could be enrolled for up to 10 years. These programs affect the demand for cropland and consequently the rate at which rangeland is converted to cropland. Thus, consideration of current and future government agricultural programs is necessary to project future rangeland acres.

Recent concerns that the Dust Bowl lessons were being relearned in the conversion of highly erodible pasture and rangeland led to legislation at county, state (Lacey 1983, Roath 1983), and national levels (Food Security Act of 1985) restricting the plowing of fragile rangelands. The Food Security Act of 1985 included several subtitles aimed at reducing crop surpluses and environmental damages associated with cropland use. The objective of the Conservation Reserve subtitle was to provide a monetary incentive to remove highly erodible cropland from production. This incentive program is referred to as the Conservation Reserve Program (CRP). The objective of the Highly Erodible Land Conservation subtitle was to remove highly erodible cropland from production as a requirement for continued eligibility for commodity program benefits. The latter subtitle contains a "sodbuster" provision wherein the plowing of highly erodible land that is not currently cropped would cause the operator to become ineligible for price-support payments, farm storage facility loans, crop insurance, and disaster payments. A similar provision called "swampbuster" restricts the plowing of wetlands. The Highly Erodible Land Conservation subtitle also contains a conservation compliance provision wherein future commodity program benefits are denied to producers who do not have specific conservation plans on highly erodible cropland now in production. These provisions were intended to take highly erodible land out of crop production, reduce erosion levels on highly erodible land, and to stem the tide of highly erodible land conversion to cropland.

The CRP is scheduled to retire at least 40 million acres of cropland by 1990. Enrollment, as of mid-1987, was 22.9 million acres. Once a farmer's bid is accepted into the program, a permanent vegetation cover must be established on the acres enrolled and the vegetation cannot be commercially harvested or grazed by livestock for the duration of the 10-year contract, except where the Secretary of Agriculture permits, as in a drought or similar emergency (Dicks et al. 1987), as occurred in the summer of 1988. The land can be used profitably for wildlife grazing through hunting or recreation. Although most acres are being planted with a permanent cover crop of either tame or native grass, over 1.2 million acres have been accepted for tree plantings, mostly in the SO region (USDA Agricultural Stabilization and Conservation Service 1987).

Enrollment in the CRP as of the fifth sign-up in mid-1987 was largest in the Northern Rocky Mountain (NR) region and least in the California (CA) region (fig. 26).



NOTE.—Hawaii included in CA Region; 29,000 acres in Alaska not shown.

Source: USDA, Agricultural Stabilization and Conservation Service (1987)

Figure 26.—Conservation reserve program as of the fifth sign-up (August 1987).

Each of the states of Colorado, Kansas, Montana, North Dakota (NR region), Iowa, Minnesota, Missouri (NO region), and Texas (SO region) have over a million acres enrolled. The national average size of the contract is 110 acres, although the size varies by region (USDA Agricultural Stabilization and Conservation Service 1987). If the regional contributions remained the same as shown in figure 26, then doubling these acres gives an indication of the likely regional distribution of enrolled acres when the national cap of 45 million acres is reached.

Heimlich (1985) suggested that the conditions favorable to land conversion during 1975-81 are not likely to reoccur in the immediate future. Hexem and Krupa (1987) mentioned factors that may discourage future cropland conversions: (1) less favorable cost/price relationships since 1981, (2) the Food Security Act of 1985, (3) changes in the federal tax code eliminating investment tax credits, capital gains exclusions, and the alteration of land development cost deductions. All regions have land that could potentially be placed in crop production (table 15). The largest areas of land with high potential for conversion occur in North and South Dakota, Nebraska, Kansas, Iowa, Missouri, Indiana, Illinois, Ohio, Oklahoma, and Texas. Seventy-six percent of the national acreage with high potential for conversion to cropland is currently in pasture and rangeland (Hexem and Krupa 1987).

LAND USE CHANGES AND RESOURCE MANAGEMENT: A REGIONAL CASE STUDY

Past assessments of natural resources have relied on a limited application of analytical approaches to project

Table 15.—Regional acreage (1,000 acres) with high and medium potential for conversion to cropland, 1982.

Region	Pasture and rangeland			Forestland		
	High	Medium	Total	High	Medium	Total
Northern	7,066	13,988	21,054	2,324	11,467	13,791
Southern	11,476	34,902	46,378	4,701	20,002	24,702
Rocky Mountain	7,317	28,406	35,723	82	429	511
Pacific Coast	1,165	3,715	4,880	144	1,837	1,981

Source: Table 5 from Hexem and Krupa (1987).

resource supplies and inventories. These assessments have been criticized for not analyzing future resource production in a multiple resource context (Schweitzer et al. 1981). In response to such criticism, Joyce et al. (1986) developed a regional modeling framework that analyzed multiple resource response to land management activities. The SO region of the United States was chosen as the test area for the application of this framework. This study, the first of its kind at the regional level, represents a prototype of how future national assessments may address regional multiple resource production.

Modeling Approach

Four distinct but closely related systems of models were linked in a multiresource framework (Joyce et al. 1986). The Timber Assessment Market Model (TAMM) estimated the future demand for wood products and the roundwood harvest needed to meet this demand (Adams and Haynes 1980). The Timber Resource Inventory Model (TRIM) projected changes in timber inventory, growth, and harvest on timber stands defined by ownership, timber management type (natural pine, planted pine, oak-pine, upland hardwoods, and bottomland hardwoods), and site class (Tedder et al. 1987). Changes in major land uses (forest, pasture/rangeland, cropland, and human-related land), timber management type conversions, and ownership were simulated with the Southern Acreage Model (Alig 1985). The impact of land area and timber management changes on the southern landscape were simulated by using resource models for white-tailed deer, wild turkey, and red-cockaded woodpecker (Flather et al. 1989), trout (Flebbe et al. 1988), water quantity (Sisler 1986), and forage (Joyce in prep.). A summary of the results for all resources is presented in USDA Forest Service (1988d). The results of the forage analysis will be presented here.

Forage Production Models

The objective of the forage component of this study was to develop production estimates based on land use, timber stand descriptions, timber management activities, and environmental characteristics. The forage model projects forage production on pasture, range, and forest

land by using environmental and management factors specific to each land type (Joyce 1988, in prep.). This study included all states in the SO region (fig. 1) except Kentucky and the western parts of Oklahoma and Texas. The South Central subregion consisted of Alabama, Mississippi, Louisiana, Arkansas, Tennessee, and the eastern parts of Texas and Oklahoma. The Southeast subregion included Virginia, North and South Carolina, Georgia, and Florida.

The modeling approach for pasture and rangelands is patterned after Sharp et al. (1976) where rates of production specific to each land type were used to estimate, along with acres within each land type, the forage production at the state level. Range forage production rates were taken from the Range Site Descriptions developed by SCS personnel within each state. Pasture forage production rates were estimated by using hay production within each state (U.S. Department of Agriculture 1984). On forested stands, the modeling approach follows Joyce and Baker (1987) where forest overstory characteristics such as timber type and volume, management practices such as burning history, and environmental characteristics such as precipitation, were statistically related to forage production. Timber stand characteristics significantly associated with forage production varied by timber management type and age class (Joyce 1988).

Modeling the possible impacts of changing land use and timber management on forage production requires a number of assumptions. These assumptions reflect acknowledgment of factors influencing forage production that could not be quantified in the model. Specifically, it was assumed that forage production changes on forested lands over the projection period are the result of changes in forest stand characteristics. Consequently, environmental factors that influence understory vegetation (e.g., climate change) are assumed to remain similar to past and current values. Timber management practices are assumed not to change in a way that will affect forage production responses over the projection period. For example, planting practices in pine plantations are assumed not to change tree density and spacing in such a way as to increase light reaching the forest floor. Pasture management practices, such as fertilization, are assumed not to change in a way that will affect forage production. Incorporating these factors into a quantitative analysis of forage production at the regional level will require further research.

Results

A future scenario was developed to represent the likely demand for timber products and the level of timber management required to ensure that the timber supplies would meet that demand for 1985 to 2030. A set of assumptions concerning population growth, economic growth, and timber management were used to generate the timber and land area projections (USDA Forest Service 1988d). A panel of forestry experts from the South, including forest industry, state forestry, and federal agency personnel developed the assumptions concerning likely future timber management actions.

Under this future, land area shifts over the entire South were dominated by a reduction of forest land by 3% and an increase in human-related land by 50%. Pasture and rangeland acres declined 7 million acres, or 14% over the projection period for the entire South. Acres in planted pine increased substantially, from 5% of the southern landscape to nearly 15%. These acres come primarily from the conversion of natural pine, but acres of upland hardwoods and oak-pine are also converted to planted pine.

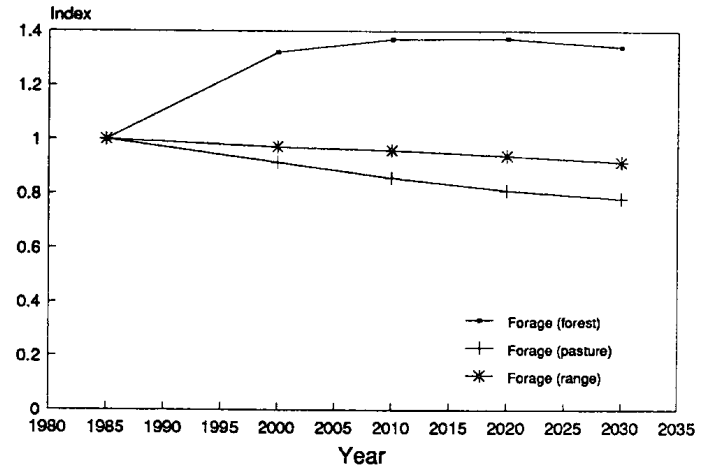
The total production of forage from all sources decreased over the projection period (fig. 27). The overall decrease reflected the southwide conversion of pasture and rangeland acres to other land uses. Forage production on forested stands increased as the older stands were harvested and regenerated, however, this increase did not compensate for the larger decreases in pasture and rangeland forage. Other factors that contributed to the increase in forest forage production included forest land conversion to planted pine types having a relatively more open canopy and management emphasis on reduction of brush.

Between 80% to 95% of the pasture in the South is currently grazed (USDA Soil Conservation Service 1987a). The results of this study suggest that if grazed roughage demands stay at their current level, forage on pasture and rangelands will be insufficient to meet the demand. Forest lands represent an extensive reservoir of grazed roughages as less than 10% are currently grazed (USDA Soil Conservation Service 1987a). The use of this forage reservoir to compensate for the decline in forages from pasture and rangelands will need to reverse an historical trend of decreased grazing on forested lands (Frey and Hexem 1985).

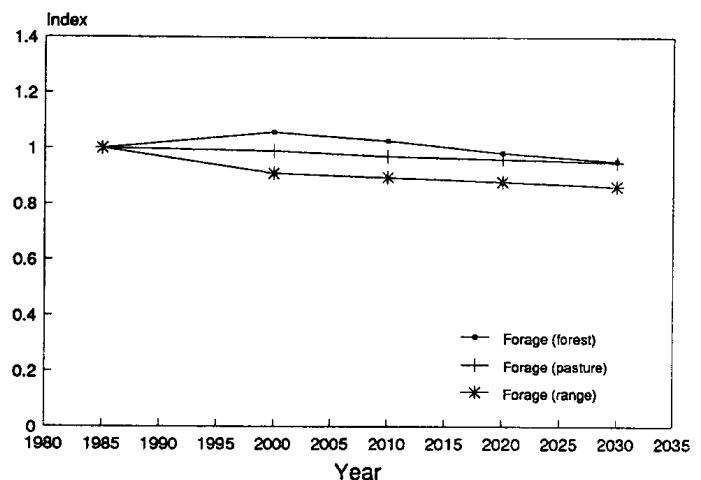
The extensive conversion to planted pine and the need to manage understory vegetation on these stands to reduce competition with the young seedlings suggests a future need for vegetation management (Pearson 1987). Increasing constraints on chemical control will necessitate alternative methods to manage this vegetation. The use of livestock as a biological vegetation control tool shows great potential in the South (Pearson 1987) as well as other places nationwide (Krueger 1987).

The results of this case study suggest methods to address multiresource interactions in national assessments. Resource models for timber, wildlife, forage, fish, and water were linked at the regional level for the first time. The importance of a consistently and completely

(a) South Central Region



(b) Southeast Region



Source: Joyce (1988)

Figure 27.—Indexed response of resources—baseline scenario.

defined land base was demonstrated in the linkages across these models. This analysis is an impact analysis that is entirely driven by the land use and the timber inventory projections. Traditionally, the use of land for grazing has been considered residual use, grazed when the land can be used for nothing else. Additional research is needed to adapt this methodology to other regions and to improve the feedbacks between resources during the projection period.

SUPPLY OF PUBLIC FORAGE

The supply of forage on public lands is reflected in the number of Animal Unit Months (AUMs) permitted to graze each year. Although these numbers are influenced by factors affecting the demand of forage on public lands, use of public grazing is an indication of the supply of forage.

National Level

Numerous federal, state, and local government agencies permit grazing on public lands. The largest suppliers of permitted grazing on federal lands are the FS with 10 million AUMs and the BLM with 12.5 million AUMs in 1986 (table 9). The 7 million AUMs that other western agencies permit is probably a minimum estimate, as only 113 out of 257 sites had AUM records (Bartlett et al. 1983). The Bureau of Indian Affairs was the largest supplier of grazing in their survey. More complete records indicate the Bureau of Indian Affairs supplies over 4.9 million AUMs of grazing (Kipp pers. comm). Other federal agencies reported by Bartlett et al. 1983 included National Park Service (81,752 AUMs), Fish and Wildlife Service (264,723 AUMs), U.S. Army (57,463 AUMs), U.S. Navy and Marines (23,632 AUMs), Agricultural Research Service (19,920 AUMs), U.S. Air Force (18,265 AUMs), Bureau of Reclamation (8,011 AUMs), and the U.S. Army Corp of Engineers (3,610 AUMs).

Historical records on NFS lands indicate that grazing has remained fairly constant since 1953 (fig. 28a). The increase in 1954 is the addition of National Grasslands to the Forest Service (table 13). The slight decline, less than 1 million AUMs, is the result of a decline in the number of sheep and goats grazing NFS lands. Reductions in cattle allotments have also occurred in some regions. Livestock grazing on BLM-administered lands⁸ has declined as a result of reductions in stocking rates on some allotments and a transfer of BLM-administered lands to other agencies (USDI Bureau of Land Management 1984) (fig. 28b). Although a breakdown by animal type was not available for Section 15 lands⁹ from BLM, trends on the Section 3 lands¹⁰ indicate a similar decline in sheep as was seen on NFS lands.

Regional Supplies from Forest Service and Bureau of Land Management

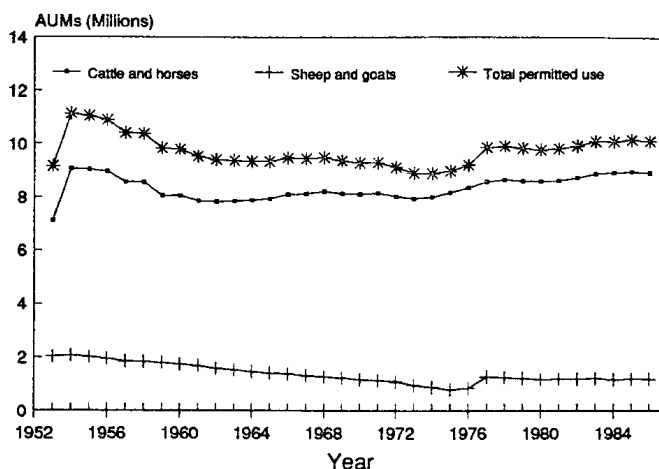
In the NR region, elevations of rangelands suitable for grazing vary from 800 feet in Kansas to over 12,000 feet on alpine ranges. Plant communities along this elevational gradient include sandhill prairies, sagebrush-grass, ponderosa pine and mountain bunch grass communities, aspen, mountain meadows, and alpine meadows (fig. 2). Although grazingland occurs on federal, state, and privately-owned land, livestock enterprises with their year-round cattle and sheep operations receive an essential component in their grazing balance

⁸To compare BLM AUMs with FS AUMs, multiple BLM AUMs by 1.2 (USDA Forest Service and USDI Bureau of Land Management 1986).

⁹Section 15 lands on BLM are public lands administered by BLM outside of grazing districts in western states leased for grazing purposes under authority of Section 15 of the Taylor Grazing Act.

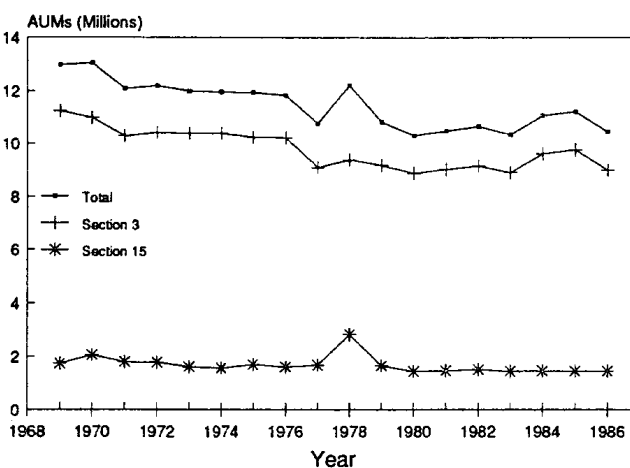
¹⁰Section 3 lands are public lands within grazing districts administered by BLM in western states leased for grazing purposes under authority of Section 3 of the Taylor Grazing Act.

(a) National Forest System lands



Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

(b) Bureau of Land Management-administered lands



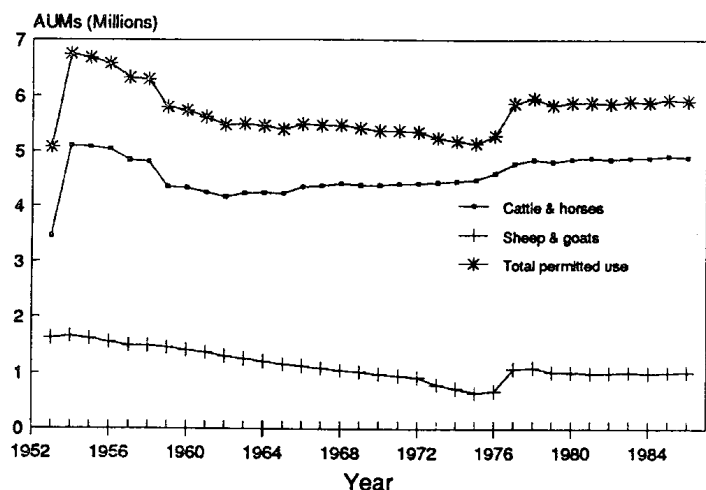
NOTE.--BLM AUMs were multiplied by 1.2 to compare with NFS.

Source: USDI, Bureau of Land Management (1969-1987)

Figure 28.—National grazing use.

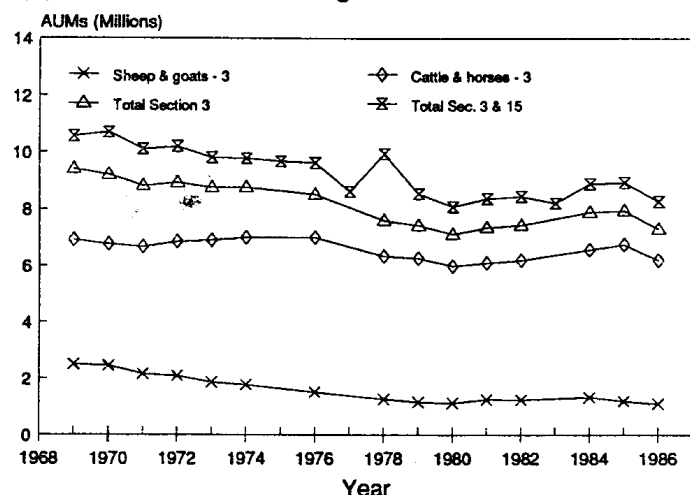
from federal lands (USDA Forest Service 1981a). Paralleling the national trend, the number of AUMs permitted to graze on public lands in the NR region has declined in 1953-86 (figs. 28 and 29). The number of AUMs on NFS lands peaked at nearly 7 million in 1954 and has declined since then to about 6 million AUMs in 1985 (fig. 29a). The early rise in 1954 reflects the inclusion of National Grasslands into the NFS, increasing the AUMs available by nearly 2 million. Cattle grazing dominates NFS use in this region. Horse use in this region is mainly pack and saddle animals for camping, hunting, and fishing trips (USDA Forest Service 1981a, 1984b). Sheep AUMs in Utah and Nevada alone totaled nearly 1 million AUMs in the 1950s but have declined to near 750,000 in the 1980s.

(a) National Forest System lands



Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

(b) Bureau of Land Management-administered lands



NOTE.—BLM AUMs were multiplied by 1.2 to compare with NFS.

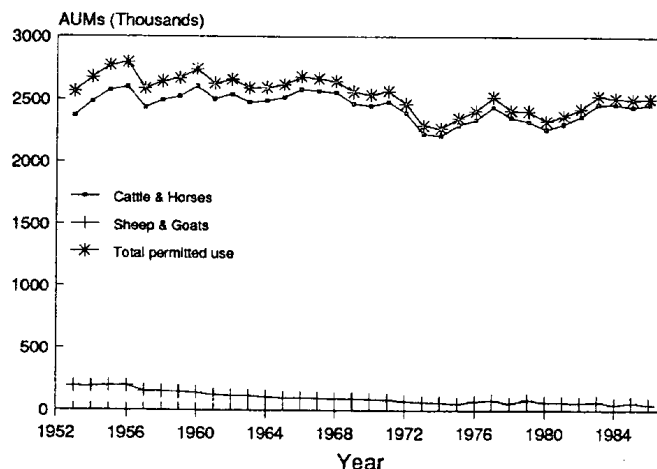
Source: USDI, Bureau of Land Management (1969-1987)

Figure 29.—Northern Rocky Mountain region grazing use.

The NR region accounts for nearly half of the national BLM AUMs. Data available from 1969 to 1986 indicate a decline from nearly 9 million AUMs permitted in 1969 to less than 8 million in 1986 (fig. 29b). Although a breakdown of sheep and cattle AUMs on Section 15 lands over time was not available, AUMs for cattle and sheep on BLM section 3 lands reflect the trends shown for NFS lands within this region (fig. 29). Sheep use has declined nearly 50%, resulting in 1 million fewer AUMs for sheep on BLM lands by 1986.

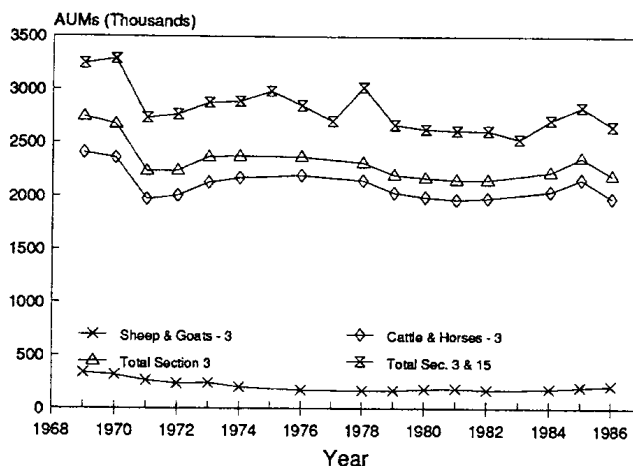
In the Southwest (SW) region, 85% of the land under all ownerships is rangeland and livestock grazing is estimated to occur on 90% of this land. Grassland, woodland, and forest ecosystems comprise the suitable grazinglands; 46% occurs in woodland ecosystems. About 45% of the NFS permittees graze livestock yearlong on

(a) National Forest System lands



Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

(b) Bureau of Land Management-administered lands



NOTE.—BLM AUMs were multiplied by 1.2 to compare with NFS.

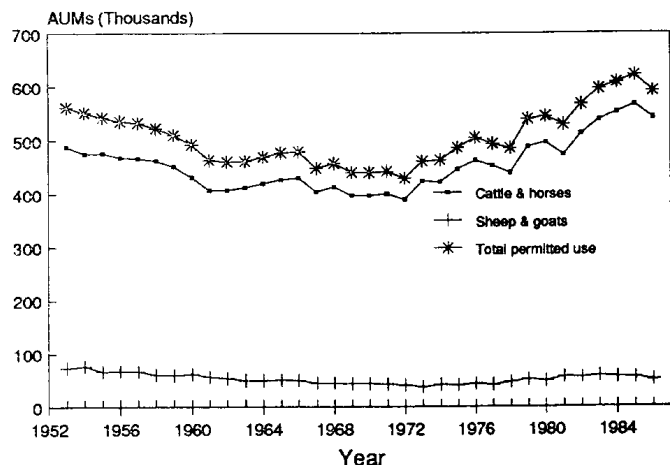
Source: USDI, Bureau of Land Management (1969-1987)

Figure 30.—Southwest region grazing use.

NFS lands (USDA Forest Service 1983a). Cattle comprise the major use of NFS grazing in this region. Permitted AUMs on NFS lands in the SW region have fluctuated around 2.5 million since the late 1950s (fig. 30a), even though regionally, cattle inventories increased 66% in the early parts of this period. Sheep and goat use on NFS lands has declined since 1953. Permitted grazing on BLM lands in the Southwest has declined from over 3.2 million AUMs in 1969 to less than 3 million in 1986 (fig. 30b). As on NFS lands, cattle comprise the major use and sheep and goat use have declined.

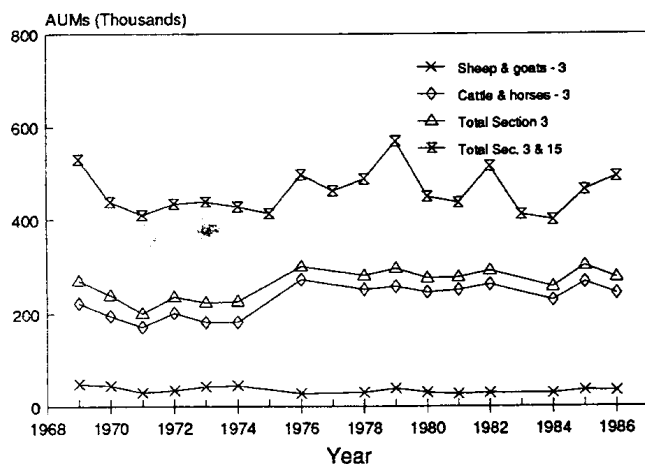
In the CA region, grazing patterns differ for the two agencies. Permitted AUMs were higher in California on NFS lands in 1984 than in 1953 (fig. 31a). The rise in total AUMs on public lands lags the rise in cattle numbers. As a percentage of the total AUMs, cattle grazing is the primary use of NFS grazinglands. Permitted sheep use

(a) National Forest System lands



Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

(b) Bureau of Land Management-administered lands



NOTE.—BLM AUMs were multiplied by 1.2 to compare with NFS.

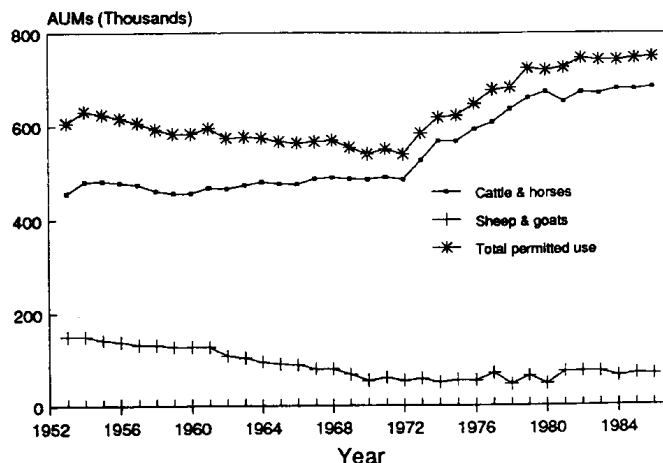
Source: USDI, Bureau of Land Management (1969-1987)

Figure 31.—California region grazing use.

has declined on NFS lands. Use on BLM lands in California is the smallest for all western regions. Total permitted grazing since 1969 has fluctuated greatly, largely because of ephemeral precipitation in the southern part of this region (fig. 31b). On Section 3 lands, sheep and goat AUMs have remained fairly constant, but cattle AUMs have continually increased over the period (fig. 31b).

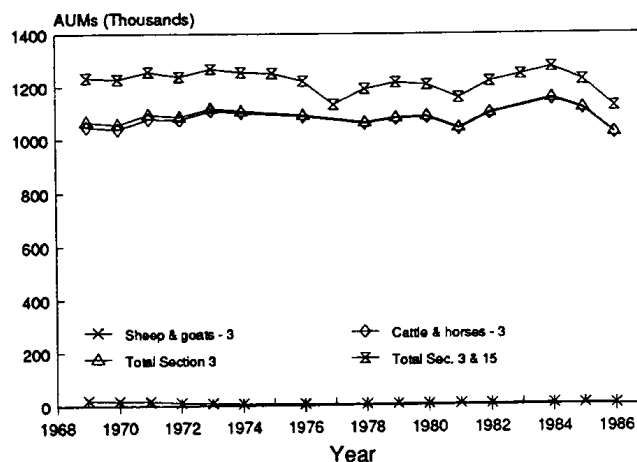
As in other western regions, grazing on public lands in the Pacific North (PN) region is important in completing the year-long feed mix within livestock enterprises. More than 80% of the grazing lands on NFS lands are forested (USDA Forest Service 1984c). Unlike trends seen in other regions, AUMs on public lands in the PN region have either increased (NFS lands) or fluctuated slightly around the same number since 1969 (BLM lands) (fig. 32). Permitted AUMs on NFS lands have increased since 1953, the result of a nearly 30% increase in cattle AUMs. Permitted sheep use has declined substantially, paralleling

(a) National Forest System lands



Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

(b) Bureau of Land Management-administered lands



NOTE.—BLM AUMs were multiplied by 1.2 to compare with NFS.

Source: USDI, Bureau of Land Management (1969-1987)

Figure 32.—Pacific North region grazing use.

the regional decrease in sheep numbers. Actual use on BLM lands has remained fairly constant since 1969 (fig. 32b). Cattle AUMs on Section 3 lands have remained fairly constant while sheep AUMs, which were a small component of BLM grazing have declined since 1969.

Only 12.5 million acres, or 3.9% of the total acres, of forest and rangeland in the SO region are on NFS lands. Of these lands, only 2 million acres are considered suitable for grazing. Thus, NFS permitted AUMs in the SO region are the lowest of all regions (fig. 33a). Only 38,000 acres of NFS lands are in vegetation types such as grassland, prairie, wet grassland, and savannah (USDA Forest Service 1984d). More grazing opportunities on southern national forests occur in regeneration areas and openings within longleaf pine and loblolly-shortleaf pine ecosystems. Although these permitted numbers represent an estimate of supply, it is important to note that additional grazing opportunities could be provided

on southern national forest lands (USDA Forest Service 1984d). The decline or break in the historical trends in the SO and NO regions is the result of grazing management operations shifting to a grazing permit system in the mid-1960s (Rowley 1986). Before this point, only approximate estimates of the grazing on these forests are available.

Although NFS lands comprise over 6 million acres in the NO region, only 880 thousand acres (14%) is considered to be suitable for livestock grazing (USDA Forest Service 1981b). As in the South, grazing opportunities are primarily forest openings or regeneration sites. Grazing on NFS lands in the NO region declined between 1953 and 1965 (fig. 33b). Cattle grazing, either dairy or beef, dominates the grazing use in this region. Sheep use is very small (3,000 AUMs). The BLM does not administer any grazing within the NO or SO regions.

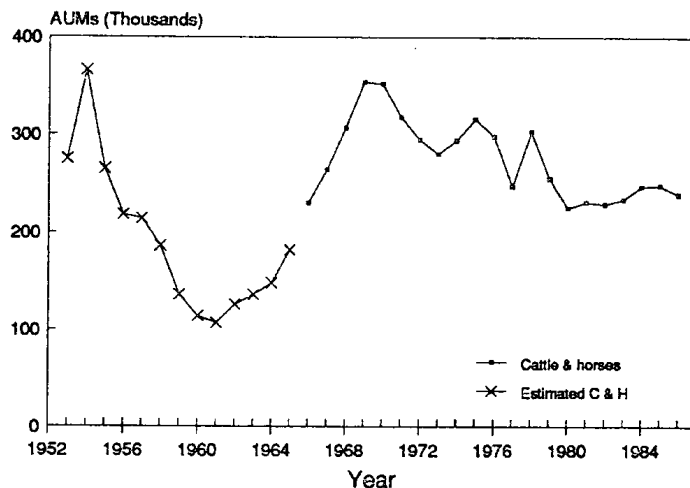
SUMMARY

Forage, that part of vegetation that is available for consumption by wild and domestic herbivores, is produced on forest land, rangeland, pasture, hayland, cropland (after crop harvest), and cropland used for pasture. Management results are influenced by the ecology of forest and range ecosystems. Past and current uses such as grazing, timber harvesting, mining, cropping and abandonment of cropland, and species introduction, have and will continue to have an effect on production from these lands. New technology, and eventually biotechnology, offers possibilities to enhance the future productivity of forest and rangelands. Economic factors, however, affect the implementation of range management technology, and the highest implementation rates have occurred for practices requiring minimal capital investment.

The management of forest and rangelands, government agricultural programs, and the environment interact to influence changes in land use across the United States. The availability of land for forage production for wild or domestic herbivores is a function of the demand for land for other uses. Conversion of forest and rangeland to a nonreversible use such as urbanland decreases the land available for forage production and for wildlife habitat. Crop prices, the demand for cropland, government programs aimed at reducing crop surpluses, and variation in acres of crops planted influence the amount of forage supplied by cropland, the conversion of rangeland to cropland, and the price of rangeland. At times, conversion of rangeland to cropland has been high, prompting legislation to regulate the flow of highly erodible land into crop production. Conditions favorable for rangeland and forest land conversion to cropland are not likely to reoccur in the immediate future because of the following factors: (1) less favorable cost/price relationships, (2) Food Security Act of 1985, and (3) changes in the federal tax code.

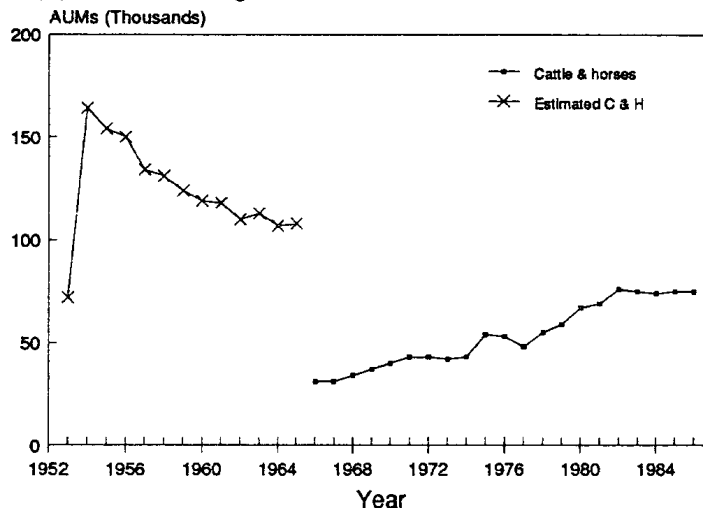
The supply of forage from public lands is set by multiple resource management objectives and public policy. Recent legislation has emphasized the multiple use of federal lands, the need to examine potential impacts of management, the management of wild horses and burros, and resource planning on federal lands. Thus, the

(a) Southern Region



Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

(b) Northern Region



NOTE.—Sheep use is about 3,000 AUMs

Source: USDA, Forest Service (1978-1987a); USDA, Forest Service (1986b)

Figure 33.—Grazing use on eastern National Forest System lands.

quantity of forage produced on public lands will be a function of multiresource management for wild and domestic grazing animals such as livestock, wildlife, and wild horses and burros, and other resource outputs such as timber, water, recreation, and scenic beauty. Multi-resource management requires a consideration of the tradeoffs in resource production.

Assessing the forage produced nationally is difficult because forage production is not inventoried. Use, not production, is quantified when forage consumption estimates are derived from herbivore inventories. Projections of forage production will be derived from projections of the likely future technological improvements in forage production, and projections of land available for forage production. These projections, based on factors discussed here, are presented in Chapter 4.

CHAPTER 3: FACTORS AFFECTING THE DEMAND FOR RANGE FORAGE

INTRODUCTION

Demand is defined as the quantity of product willingly bought per unit of time at a specific price¹¹ (Workman 1986). Less than 10% of forage consumed by livestock is leased or sold in an observable market (table 10). The price of forage from Forest Service (FS) land and on Bureau of Land Management (BLM) administered land is set by federal law. The price for forage from private lands is not usually determined by competitive bidding within a market system because this forage is often produced within the farm or ranch enterprise. Forage for wild herbivores is not usually priced in a market. Without an observable market for most of the forage consumed, the national demand for forage is difficult to analyze in terms of the traditional supply/demand equilibrium analysis of commodities as described for beef by Workman (1986).

Forage produced on forest and rangelands is intermediate to the production of the final output, such as wildlife, livestock, wild horses and burros (Bartlett 1986). The demand for the final output, the herbivore, can be used to derive the future demand for range forage. Forest and rangelands also provide other commodity outputs and noncommodity outputs (chapter 1). The management of forest and rangelands must be responsive to the demand for forage and the demand for other range outputs. Research is needed to determine the value of range vegetation in the production of these outputs (Bartlett 1986), and to develop a method for allocating the range resource across these demands (Broken and McCarl 1984).

The present chapter addresses the factors that affect the demand of range forage as derived from the demand for domestic herbivores. The demand for livestock is a function of society's demand for market commodities such as meat, hides, wool, tallow, and secondary products such as pharmaceuticals (Council for Agricultural Science and Technology 1986, USDA Forest Service 1980). About 78% of the gross income from sheep and lamb is attributed to meat, primarily lamb, with the remaining income from the sale of wool. In 1982, 73% of the cash receipts from the sale of all meat animals were from marketing cattle and calves (Nelson 1984).

Forage demand for livestock production depends on the technology associated with livestock production, the prices of alternative feeds, the total feed mix, and the price of livestock. The price of beef cattle or sheep depends upon the interactions between the supply and

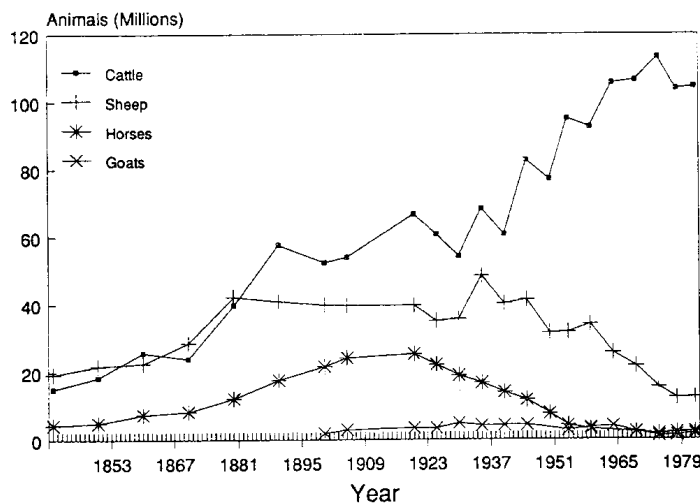
the demand of meat. The supply of meat is determined by the cost structure of production. The demand for meat is a function of export demand and domestic consumption. The demand for beef or lamb meat is related to consumer tastes and preferences, disposable income, changes in human population size and age distribution, and the relative prices of alternative foods, particularly other meats.

The demand for wild herbivores is a function of society's demand for nonconsumptive recreation, such as nature walks, and consumptive recreation such as hunting. Society's desire for recreational experiences associated with wild herbivores has increased the value of these grazing animals. Meeting the forage requirements of livestock and wildlife is an important management objective on public and private lands. Projections of the future demand for wild herbivores, made by Flather and Hoekstra (in press), are compared with this report's projections for domestic herbivores in Chapter 5.

LIVESTOCK PRODUCTION IN THE UNITED STATES

Historical Livestock Numbers at the National Level

Cattle and sheep inventories were nearly equal in 1840 and both animal types increased until 1880 when sheep inventories leveled off (fig. 34). Cattle numbers continued to increase until 1975 when inventories reached



NOTE.—Only source of consistent data for all animal types:
latest census: 1982.

Source: USDC, Bureau of Census (1935-1982)

Figure 34.—Number of livestock on farms in the United States.

¹¹This assumes all other prices, population, income, tastes, preferences, and any other factors that might affect quantity demanded are held constant.

their historical peak and began to decline. Sheep numbers peaked in the mid-1930s at about 56 million head and have since dropped to 10 million head in 1986 (USDA 1987). Horse numbers increased with the westward expansion of agriculture to a peak of 20 million in the 1920s. At this time the tractor was introduced, and mechanical power gradually replaced horses. In 1982, horse inventories were around 2 million animals on farms, or 5 million if the growing numbers of recreational animals are included. Goat inventories have historically been small compared with other grazing animals (fig. 34). In 1984, about 1.5 million goats were reported in the United States, mostly in Texas (USDA Statistical Reporting Service 1985).

Historical Livestock Numbers at the Regional Level

Cattle numbers in western regions increased from 17% to 35% over 1955 numbers (table 16). Sheep numbers dropped to levels ranging from 37% to 51% of the 1955 inventories. In the Northern Rocky Mountain (NR) region, cattle numbers rose continually until they peaked

in 1974 at 34 million (table 16). By 1986, cattle numbers were at only 79% of the 1974 peak but 117% of the 1955 level. Sheep inventories rose to 11 million animals in 1959 and declined thereafter. By 1986, sheep numbers were 34% of the 1955 inventory in the NR region. In the Southwest (SW) region, cattle numbers increased nearly 66% between 1955 and 1973 to 3.0 million, and then declined to 2.4 million by 1986 (table 16). Southwestern sheep numbers have declined since 1955 and in 1986 were less than 50% of the 1955 inventory. Cattle inventories within the California (CA) region have sustained the greatest increase of all western regions, 138% of the 1955 inventory in 1986 (table 16). Sheep numbers have followed the national trend. Cattle numbers in the Pacific North (PN) region have increased since 1955; sustained declines occurring only since 1980. Sheep numbers in the PN region have paralleled the national trend.

Cattle numbers in the eastern regions (Northern and Southern) rose only 4% from 1955 to 1986, whereas sheep numbers declined 75% (table 17). In contrast to national increases between 1955 and 1974, cattle numbers in the Northern (NO) region remained fairly constant, a reflection of this region's dairy industry. After

Table 16.—Livestock numbers (1,000 head) in the western United States by assessment region.

Year	Northern Rocky		Southwest		California		Pacific North	
	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep
1955	22,927	9,904	2,147	1,627	3,863	1,700	2,646	1,105
1956	23,158	9,912	2,234	1,581	3,863	1,700	2,674	1,075
1957	21,346	9,906	2,087	1,587	3,870	1,632	2,520	1,080
1958	21,887	10,827	1,999	1,591	3,733	1,616	2,545	1,095
1959	23,071	11,103	2,133	1,647	4,044	1,600	2,675	1,146
1960	24,144	10,742	2,377	1,743	4,274	1,712	2,824	1,185
1961	23,071	10,440	2,221	1,606	4,207	1,763	2,643	1,150
1962	23,796	10,157	2,262	1,583	4,232	1,657	2,703	1,082
1963	25,631	10,190	2,339	1,550	4,778	1,541	2,835	1,004
1964	27,234	9,850	2,341	1,515	4,902	1,526	2,963	953
1965	27,397	9,344	2,246	1,420	4,913	1,511	3,054	859
1966	28,122	9,173	2,244	1,434	5,022	1,511	2,917	838
1967	28,729	9,292	2,489	1,315	5,119	1,412	2,947	667
1968	28,837	8,336	2,506	1,237	5,168	1,370	2,931	632
1969	29,007	7,849	2,552	1,227	5,140	1,234	2,863	613
1970	29,733	7,518	2,688	1,215	5,107	1,185	2,853	574
1971	31,036	7,252	2,661	1,192	5,020	1,149	2,894	544
1972	31,954	7,066	2,804	1,122	4,907	1,011	2,891	530
1973	32,477	6,681	3,035	1,084	4,952	956	2,903	491
1974	34,281	6,349	3,005	1,057	5,490	980	2,850	477
1975	32,997	5,626	2,890	930	5,450	910	2,890	432
1976	31,313	5,028	2,930	927	5,245	870	2,875	402
1977	29,675	4,483	2,565	910	4,990	900	2,870	374
1978	28,919	4,270	2,685	924	4,664	915	2,765	366
1979	28,634	4,162	2,700	935	4,915	965	2,850	406
1980	28,865	4,021	2,650	935	4,763	1,000	3,154	435
1981	29,905	4,178	2,475	920	4,980	1,030	3,200	500
1982	29,935	4,536	2,500	915	5,228	1,010	3,380	543
1983	30,165	4,526	2,450	858	5,130	920	3,220	450
1984	30,340	4,041	2,370	786	5,226	900	3,360	412
1985	28,695	3,962	2,460	718	5,181	870	3,120	398
1986	26,975	3,459	2,440	686	5,209	860	3,035	383

Source: U.S. Department of Agriculture (1955-1987), *Agricultural Statistics*.

Table 17.—Livestock numbers (1,000 head) in the eastern United States by assessment region.

Year	Northern		Southern	
	Cattle	Sheep	Cattle	Sheep
1955	35,646	5,778	29,363	7,114
1956	36,079	5,832	29,457	6,871
1957	36,013	5,919	28,666	6,414
1958	35,371	6,204	28,432	6,670
1959	35,482	6,198	29,245	7,135
1960	36,715	6,146	31,186	7,688
1961	35,405	5,689	29,772	7,469
1962	36,013	5,535	30,494	6,961
1963	36,549	4,945	31,596	6,485
1964	36,589	4,553	32,451	6,118
1965	36,765	4,558	32,801	5,549
1966	35,340	4,264	32,884	5,874
1967	35,084	3,722	34,269	5,263
1968	34,545	3,501	34,817	4,595
1969	34,491	3,378	35,823	4,347
1970	34,784	3,249	37,129	3,932
1971	34,918	3,092	37,932	3,988
1972	35,643	2,678	39,654	3,560
1973	35,961	2,522	42,197	3,278
1974	37,180	2,271	44,855	3,193
1975	38,278	2,023	49,312	2,904
1976	38,360	1,800	47,248	2,804
1977	37,172	1,899	45,530	2,676
1978	35,574	1,765	41,760	2,637
1979	33,611	1,766	38,145	2,545
1980	33,807	1,798	37,945	2,540
1981	34,533	1,847	39,220	2,446
1982	34,492	1,958	40,060	2,613
1983	33,780	1,688	40,445	2,347
1984	32,646	1,584	39,949	2,056
1985	31,655	1,485	38,598	1,914
1986	30,425	1,405	37,375	1,939

Source: U.S. Department of Agriculture (1955-1987), *Agricultural Statistics*. NOTE: Oklahoma and Texas are included in the Southern region.

1976, however, cattle numbers followed the national decline, dropping from 38 million to 30 million in 1986. Sheep numbers in the NO region also reflected the national trend. In 1955, cattle numbers in the Southern (SO) region were only 82% of cattle inventories in the NO region (table 17). By 1986, cattle inventories were greater in the South than the North. A continuous decline in southern sheep inventories has occurred since 1955 (table 17).

The largest inventories of cattle are in the NR region, the NO region, and the SO region (tables 16 and 17). The 17 western states support more than 80% of the Nation's sheep inventory (Council for Agricultural Science and Technology 1982). About 20% of the nation's sheep herd is in Texas. Large sheep inventories are also in California, Wyoming, South Dakota, Utah, New Mexico, Montana, and Colorado. Between 1960 and 1982, sheep production in the western regions rose from 75% to 82% of the national total. This shift from east to west may be related to the conversion of pasture land to crop production in the east and a trend toward agricultural specialization (Gee and Madsen 1988).

Cattle Cycles

Cycles in cattle inventories are initiated when producers, responding to rising economic indicators such as cattle prices, build up their herds. Because producers must wait nearly 3 years from the time a heifer is bred until its calf is old enough to enter the breeding herd (Gilliam 1984), the expansion part of the cycle (cattle numbers increasing) lasts from 5 to 6 years. Forage demands increase during this part of the cattle cycle. With greater cattle supply, prices begin to decline, and the producers begin to liquidate their herds until supply is low and prices begin to rise. The cycle commences again.

The last two cycles, starting in 1967 and in 1980, have not followed the dynamics of previous cycles (Gustafson 1983). Cattle numbers in the 1967-79 cycle peaked in 1975 at over 130 million head. By 1979, cattle numbers had dropped 21 million head, a 16% decline. Herd expansion in the next cycle added only 4.6 million head to the national inventory. Unlike previous cycles, this expansion did not increase the national herd over historic levels (fig. 34). Inventory on January 1, 1987 was 102 million head, 21% lower than 1975 levels.

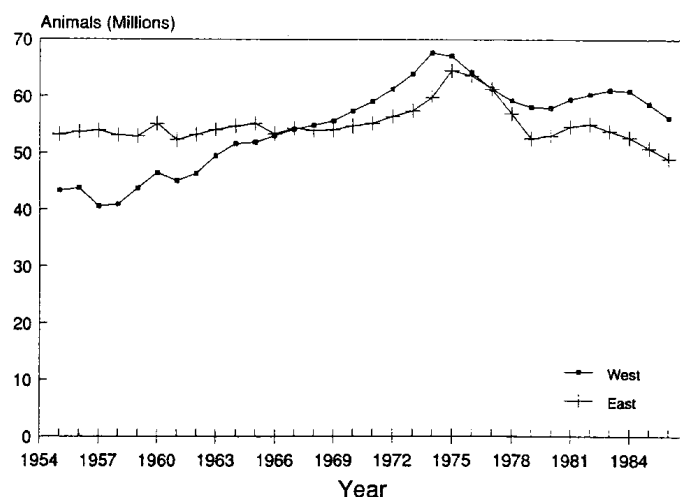
These recent aberrations in the cattle cycle may be the result of several factors. The rise during the 1967-79 cycle reflected an expanding forage base from highly productive cropland shifting to cropland pasture and increased use of cheap fertilizer (Gustafson 1983). The rapid cattle decline coincided with rising grain prices, rising energy prices, and land shifting back into crop production. Herd expansion during the 1980 cycle was small, reflecting the agricultural financial crisis, and record high total meat supplies (Gustafson 1983). Bobst and Davis (1987) estimated that each million acre addition in harvested cropland (cropland expansion implied a decrease in pasture) was associated with a decline of nearly 37,000 beef cows.

In terms of forage supplies, the dynamics of these cattle numbers give an indication of the forage potential within the cattle production system. Eastern livestock operations are more closely associated with crop production than livestock operations in western United States (Gilliam 1984). Thus, the changes in land used for crops in the eastern United States will impact the forage available for grazing animals. A comparison of livestock numbers in the West (all western assessment regions plus Oklahoma and Texas), and in the East (NO and SO regions minus Oklahoma and Texas) indicates a shift of livestock production from eastern to western regions over 1955-86 (fig. 35). Livestock production in the West expanded much more rapidly than in the East. National cattle numbers have declined 21% between 1975 and 1986, but the decline has been much greater in the East (24%) than in the West (17%). Although a decline might indicate a surplus of grazed roughages in the Nation's cattle production system, the decline in the East may be more related to shifts in cropland use from pasture to crop production (Gustafson 1983). The decline in the West, which also represents a shift from cropland pasture to crop production, may be truly representative of a surplus in forage, as much of the land grazed is forest and rangelands and not suitable for cropland.

FORAGE CONSUMPTION

National and Regional Forage Consumption by Livestock

Beef cattle and sheep represent the largest inventories of livestock that use grazed roughages in the United States. Dairy cattle make up a small part of the national inventory, and, since 1985, have declined further in response to the legislated dairy herd reduction program. Harvested forages, such as hay, and concentrate provide most of their diet. Gee and Madsen (1988) estimated that the annual consumption of grazed roughages by goats is about 3.6 million AUMs, a small amount nationally when compared with the consumption of 431 million AUMs by beef cattle and sheep (table 10). The demand for grazed forages by the 2 million farm horses is also small in comparison to beef cattle. The feed demand by horses, including recreational horses, could potentially be greater than the demand by sheep. The feed sources



NOTE.—East: NO and SO regions except Oklahoma and Texas;
West: all other regions and Oklahoma and Texas.
Source: USDA (1955-1986)

Figure 35.—Number of cattle in the eastern and in the western United States, 1955-1985.

for recreational horses, however, are primarily purchased hay. Some hog production systems use pasture, but USDA Economic Research Service (1985) reported that less than 1% of hog feed costs are for pasture. Smith et al. (1980) estimated that hogs and horses consumed less than 3% of the total nutrients supplied by forages nationwide. Because the combined total demand for grazed forage by dairy cattle, goats, and horses is small compared with beef cattle and sheep, the consumption of grazed forages is analyzed only for beef cattle and sheep in this assessment.

The main sources of forage consumed by beef cattle and sheep are deeded nonirrigated rangeland and pasture, publicly owned grazing land (i.e., federal, state, local governments), deeded irrigated pasture, and crop residues. Although the importance of enterprise-owned land is evident in that this source provides over 70% of forage consumed by beef cattle and sheep (table 10), other sources may represent the only available forage during certain seasons of the year. The regional combinations of deeded land with other forage sources (table 18) is a function of the availability of other sources, the local environment, and the type of livestock operation. The large relative contribution of public grazing in the SW and the NR regions is a reflection of the extensive amount of public land in those regions (table 5). Because of the availability of public forage, a ranch may raise hay on private land to support the livestock during the winter. The regional significance of crop production as a land use is seen in the NO region (fig. 8) where crop residues are the only source, other than deeded land, associated with beef cattle operations (table 18). The availability of irrigation in the CA and the PN regions is evidenced by the importance of irrigated pasture here in contrast to other regions. Although irrigation is available in the SW region, specialty crops bring a higher return than irrigated pasture.

Table 18.—Consumption of grazed forages by beef cattle and sheep on an animal unit month (AUM) basis, 1985.

Region	Deeded non irrigated		Public grazing		Irrigated grazing		Crop residue		Total
	Thousand AUMs	Percent	Thousand AUMs	Percent	Thousand AUMs	Percent	Thousand AUMs	Percent	Thousand AUMs
Beef Cattle									
PN	9,929	74	611	5	2,162	16	671	5	13,373
CA	12,118	79	1,048	7	1,702	11	498	3	15,367
SW	8,310	64	4,448	34	88	1	109	1	12,956
NR	95,746	81	11,452	10	3,804	3	7,777	6	118,780
NO	66,118	94	—	—	—	—	3,926	6	70,044
SO	167,137	92	6,603	4	801	T ¹	7,030	4	181,571
Total	359,359	87	24,163	6	8,557	2	20,011	5	412,090
Sheep									
PN	254	31	466	57	41	5	57	7	818
CA	1,055	52	183	9	203	10	589	29	2,029
SW	838	59	298	21	100	7	185	13	1,421
NR	2,369	31	4,356	57	382	5	535	7	7,642
NO	2,184	70	—	—	—	—	936	30	3,120
SO	4,042	100	—	—	—	—	—	—	4,042
Total	10,742	56	5,304	28	725	4	2,302	12	19,073
Beef Cattle and Sheep									
PN	10,182	72	1,078	8	2,203	16	729	5	14,191
CA	13,174	76	1,230	7	1,905	11	1,087	6	17,369
SW	9,148	64	4,747	33	188	1	294	2	14,376
NR	98,116	76	15,809	13	4,186	3	8,312	7	126,422
NO	68,303	93	—	—	—	—	4,862	7	73,165
SO	171,179	92	6,603	4	801	T	7,030	4	185,612
Total	370,101	86	29,466	7	9,283	2	22,312	5	431,163

Note: Totals may not add up as a result of rounding.

¹T = Less than 1%

Source: Gee and Madsen (1988).

Crop residue, irrigated pasture, and public grazing supply a greater share of the feed mix for sheep than for cattle (table 18). Nationally, public grazing land contributes 28% of the total feed mix for sheep, whereas this is only 6% of the total feed mix for beef cattle. In the PN, and the NR regions, public grazing contributes more than 50% of the total feed mix for sheep whereas deeded non-irrigated land contributes only 30%. Nationally, crop residue contributes 12% to the total feed mix for sheep, but only 5% for beef cattle.

Total forage consumption estimates based on ranch/farm surveys (table 18) are compared with estimated feed requirements based on national livestock inventories (table 19). Over 670 million AUMs are needed to meet the total feed requirement of beef cattle (excluding cattle in commercial feedlots) (table 19). Based on the ranch budgets, 61% of this total feed requirement, or 431 million AUMs, is met by grazed forages (table 18). For sheep (excluding lambs in feedlots), 90% of the annual feed requirements are met with grazed forages (table 19). These percentages of the total feed mix supplied by grazed forages appear reasonable, given the distribution of livestock operations in the United States (Gee and Madsen 1988). Few areas have large beef cattle inventories and 12 months of grazed forages available, implying

that a certain percentage of the cattle diet will need to be met with harvested forages or concentrates. In many areas, grazing is limited to 6 or 7 months because of adverse climatic conditions (Gee and Madsen 1988). Sheep are more dependent on grazed forages than cattle. Little supplementary feed is used in the production of sheep in the 17 western states with the exception of several months in the Northern Great Plains (Gee and Madsen 1988). These grazed forage estimates (table 18) form the basis for an examination of the regional distribution of grazed forages by livestock type, and the future demand of forage by livestock type.

Use of Livestock Forage on Public Lands

Permitted AUMs represent the amount of forage available for livestock grazing on public lands and were given as an estimate of the supply of forage from public lands (Chapter 2). Livestock are authorized to graze an allotment under a grazing permit, grazing agreement, livestock use permit, or other authorizing document. Annually, only about 1% of the grazing allotments on National Forest System (NFS) and BLM-administered lands are vacant (without a grazing agreement with a

Table 19.—January 1 inventory (1,000 head) of and estimated feed requirements (1,000 units) for beef cattle and sheep in the United States, 1985.

Livestock	Inventory	Animal units ¹	Animal unit months
Beef cattle:			
Cows that have calved	35,393	44,949	
Replacement heifers	6,183	3,833	
Steers 500 pounds and over ²	6,560	4,067	
Bulls	2,411	3,014	
Total cattle		55,863	670,356
Sheep:			
Stock sheep 1 year and older			
Ewes	7,233	1,447	
Rams and wethers	314	63	
Stock sheep, lambs			
Ewes	1,016	203	
Rams and wethers	284	57	
Total sheep		1,771	21,252
Total cattle and sheep			691,608

¹Conversions to animal units are cows, 1.27; yearlings, 0.62; and bulls, 1.25. All sheep have the same animal unit value and five head equals one animal unit.

²Assumes 30% of steers in January inventory used grazed forages. The remainder went to feedlots for finishing.

Source: Gee and Madsen (1988).

permittee) (USDA Forest Service and USDI Bureau of Land Management 1986). Most of these vacant allotments are high-elevation sheep allotments for which demand has declined because of remoteness, cost of operation, labor shortages, and the decline in the sheep industry. A permittee may elect to take non-use on an allotment. Non-use is an authorization to refrain from grazing livestock without the loss of preference for further consideration (USDA Forest Service and USDA Bureau of Land Management 1986). One indication of the demand for forage is the trend of those AUMs in non-use on NFS lands.¹²

Cattle non-use on NFS lands increased from less than 10% in 1977 to 14% in 1986 (fig. 36). Although permitted use on NFS lands has remained fairly constant from 1980 to 1986 (figs. 28-33), this increasing non-use reflects the general economic decline in the agricultural sector. This 1977-86 period coincided with the continual decline in the national cattle herd (fig. 34).

Sheep non-use fluctuated from a high of 26% to a low of 19%; no definite trend occurred in 1977-86. Although the sheep non-use percentage is higher than the cattle non-use, in terms of AUMs, this percentage represents a much smaller number of AUMs than cattle non-use. In 1980, total AUMs for sheep and goats (authorized to graze) were 1.1 million in contrast to the 8.5 million AUMs for cattle.

Regional trends of total non-use AUMs (cattle, horses, sheep, and goats) show a slight increase since 1977, reflecting the dominance of cattle AUMs. Trends in

non-use are similar across the western regions (NR, PN, CA, SW), increasing from 10% in 1977 to about 15% in 1986 (fig. 37). Non-use in the eastern regions (NO and SO) was higher than in the western regions (fig. 37), perhaps reflecting the increased emphasis of crop production in the eastern regions.

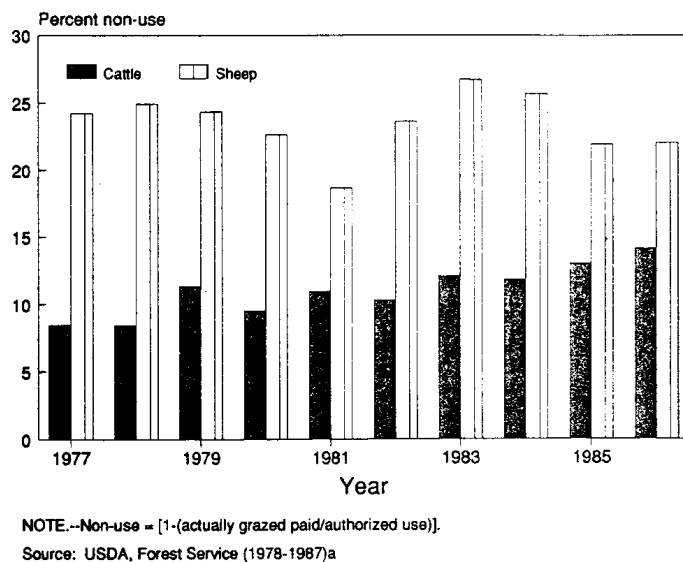
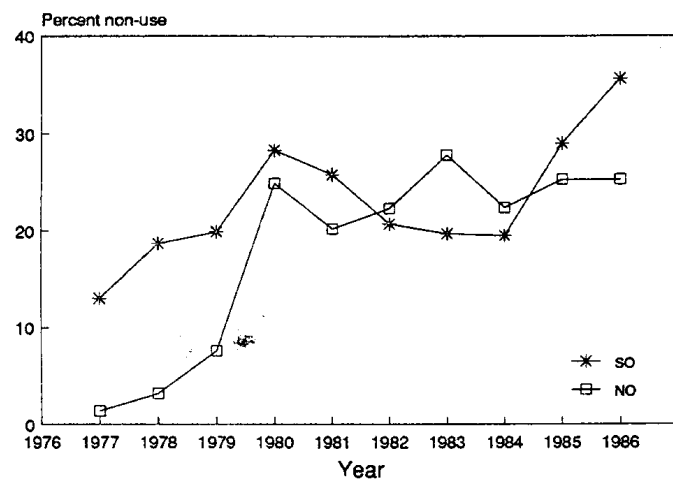
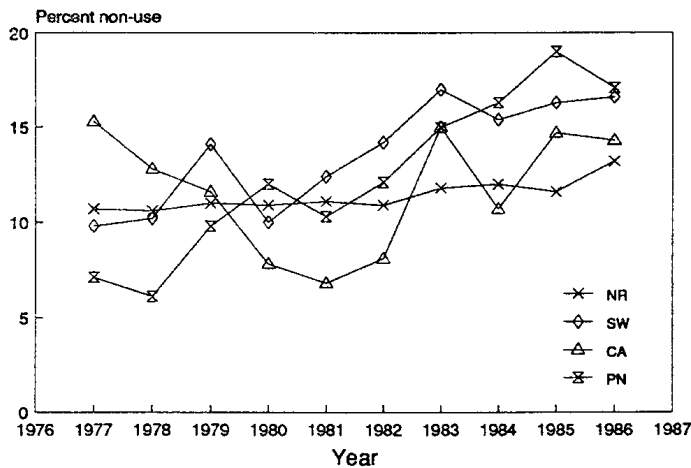


Figure 36.—Non-use of cattle and sheep permitted use on National Forest System lands.

¹²For this study, non-use percent is calculated as [1 - Actually grazed Paid Permits / Authorized to Graze] times 100 from data in the Annual Grazing Reports of the Forest Service. No data was available for the BLM.



NOTE.--Non-use = $[1 - (\text{actually grazed paid/authorized use})]$.

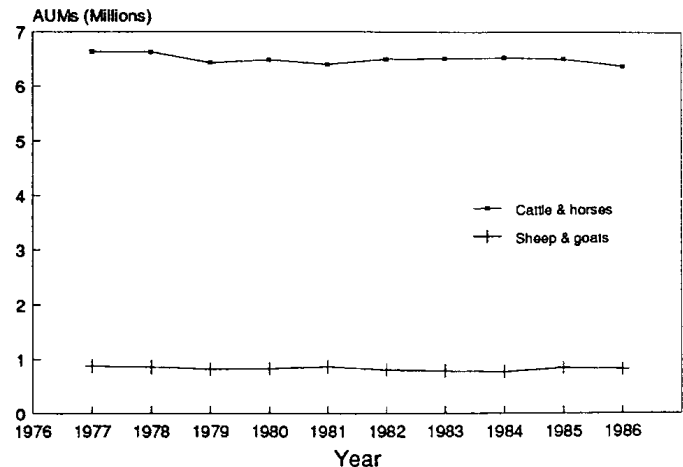
Source: USDA, Forest Service (1978-1987a)

Figure 37.—Non-use as a percentage of authorized grazing on NFS lands by assessment regions.

Wild Herbivore Populations and Domestic Grazing Use on National Forest System Lands

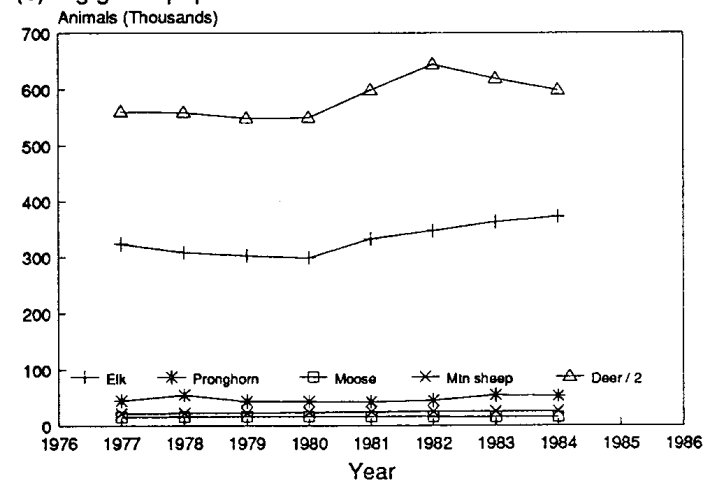
Wild and domestic herbivores graze forest and range-lands. Wildlife populations are not managed in the same manner as cattle and sheep. Livestock are managed for restricted movement, whereas wild herbivores migrate across the landscape in response to habitat, food, and water needs. Population estimates for NFS lands reflect wildlife use of those lands (Flather and Hoekstra in press, USDA Forest Service 1978-1987b), however the migratory habits of big game animals result in the use of different ownerships (surrounding private and other public lands) at different times of the year. Thus, trends in wildlife numbers reflect management from a mosaic of land ownerships. Livestock use on NFS lands is closely regulated and data on actual use by livestock (livestock actually grazed paid permitted AUMs) is

(a) Paid permitted livestock use



Source: USDA, Forest Service (1978-1987a)

(b) Big game populations



NOTE.--Wildlife data only available to 1984.

Mountain sheep includes bighorn sheep and mountain goats.

Source: USDA, Forest Service (1978-1987b)

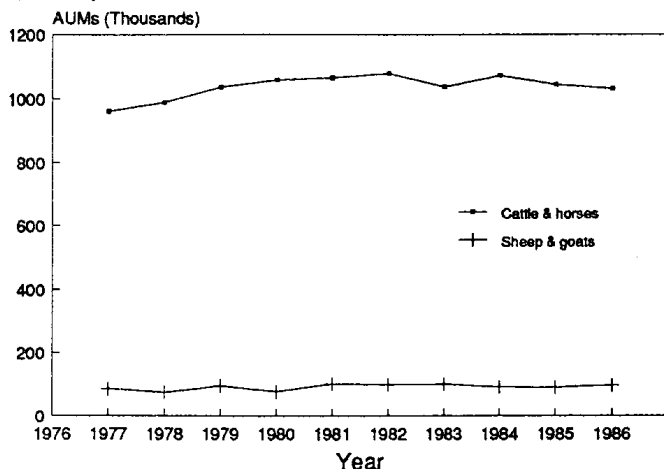
Figure 38.—Large herbivores using National Forest System lands in the Rocky Mountain region.

reported yearly (USDA Forest Service 1978-1987a). Information was available to compare wild and domestic herbivore trends on NFS lands only.

Nationally, big game populations on NFS lands have remained stable or have increased, whereas livestock permitted AUMs have remained stable or declined since 1977 (fig. 28). Before 1977, mule and black-tailed deer populations declined across all ownerships. Domestic sheep AUMs on NFS lands have continued a steady decline (fig. 28). Big game abundance has increased most notably for moose, elk, and bighorn sheep.

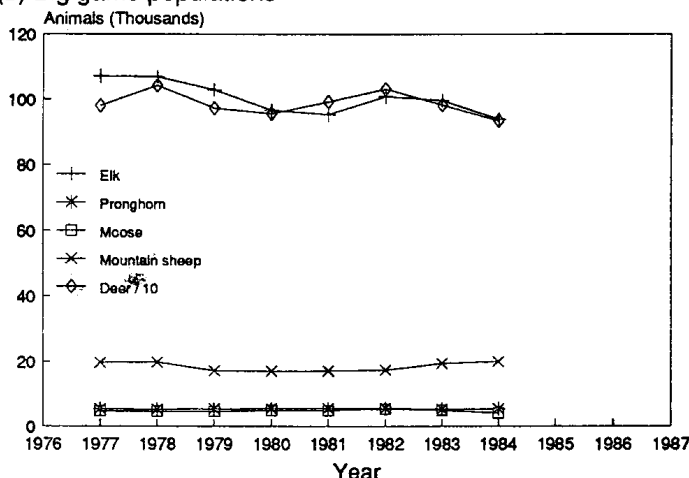
In the Rocky Mountain region (NR and SW regions), livestock actual use has declined 4%, while numbers of deer and elk have increased 6% and 15%, respectively, over 1977-86 (fig. 38). Pronghorn numbers, small relative to deer and elk, have increased 17% since 1977.

(a) Paid permitted livestock use



Source: USDA, Forest Service (1978-1987a)

(b) Big game populations



NOTE.--Wildlife data only available to 1984.
Mountain sheep includes bighorn sheep and mountain goats.

Source: USDA, Forest Service (1978-1987b)

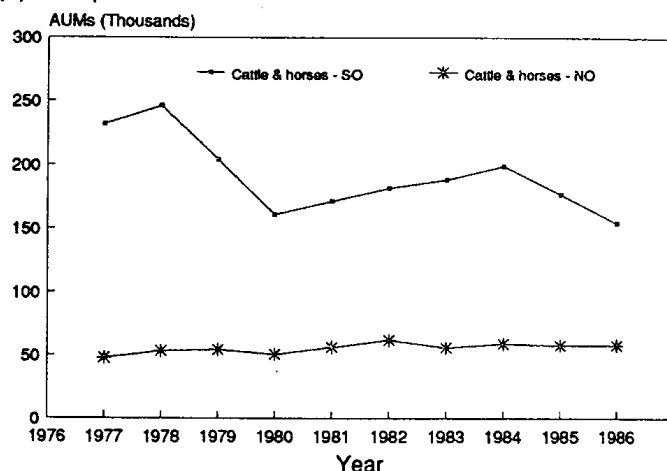
Figure 39.—Large herbivores using National Forest System lands in the Pacific Coast region.

Moose numbers have remained relatively stable, while bighorn sheep numbers have increased 28% (fig. 38b).

In the Pacific Coast region (PN and CA regions), cattle and horse AUMs have increased 7% over the 1977 levels, while deer and elk numbers have declined 5% and 12%, respectively (fig. 39). The slight rise in wild mountain sheep (bighorn sheep and mountain goats) is a reflection of increases in mountain goat populations.

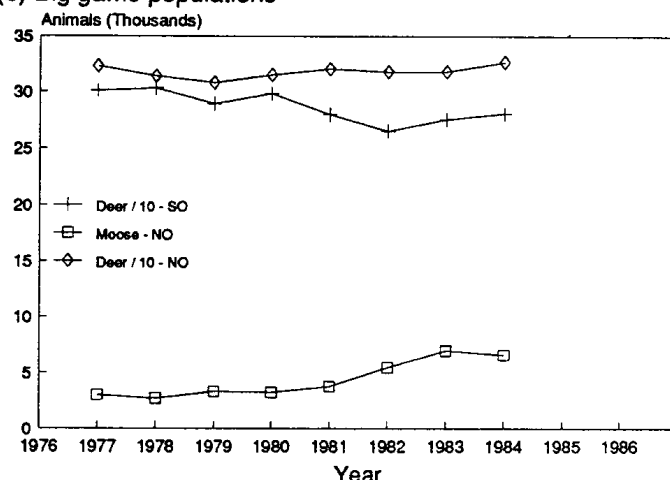
Large herbivore use on NFS lands in eastern United States (fig. 40) shows that in the NO region, cattle and horse AUMs have increased 21% since 1977. Domestic sheep use has declined 86%; AUMs dropped from 2 million in 1977 to 249,000 in 1986 in the NO region. Deer numbers on NFS lands have remained fairly constant, although declines in the 1970's possibly were related to declining forest land area in early successional stages

(a) Paid permitted livestock use



Source: USDA, Forest Service (1978-1987a)

(b) Big game populations



NOTE.--Wildlife data only available to 1984.

Source: USDA, Forest Service (1978-1987b)

Figure 40.—Large herbivores using National Forest System lands in the eastern United States.

(Flather and Hoekstra in press). Moose numbers have doubled in the NO region since 1977 (fig. 40b). In the SO region, livestock AUMs and deer numbers both declined in 1977-86, however the declines were greater for livestock (fig. 40). Over a longer period of time, white-tailed deer numbers appear to be stable, fluctuating between 250,000 to 300,000 animals (Flather and Hoekstra in press).

DEMAND FOR FORAGE BY LIVESTOCK

Beef Industry Structure

The availability of grazed forages is critical in two segments of the beef cattle industry: breeding herds and stocker cattle production. Little grazed forage is used in

this last segment of the beef industry, fed beef production, but this final step influences the retail product, and thus, can influence the demand for grazed forages. The objective of a beef cow-calf operation is to maintain and breed cows for the primary purpose of producing stocker calves and yearlings. Most stocker cattle enterprises seek to produce animals of weight and condition that will go easily into a finishing program upon entering commercial feedlots (Gee and Madsen 1988). Although some stocker cattle are slaughtered, most stocker cattle are placed in feedlots and fed grain and concentrates before slaughter.

Breeding Herds

Based on January 1 inventory numbers, the breeding herds are primarily in the SO (46% of the total), the NR (28%), and the NO (19%) regions (table 20). This regional distribution has changed little from 1978 to 1986. The largest increase in cow numbers was in the NR region with over 1 million additional cows and the largest decrease was in the NO region with about 500,000 fewer cows (Boykin et al. 1980, U.S. Department of Agriculture [various years]).

Nationally, less than 50% of all beef cows are in herds of more than 100 cows. Within the northeastern United States, small herds of less than 20 cows make up more than 50% of the total cow inventory, whereas in the western regions, less than 6% of the cow inventory is in small herds (Gilliam 1984). Operations are much larger in the western regions where 30% of the beef cows are in operations of 500 or more brood cows.

The number of producers with fewer than 20 brood cows represents a greater proportion of the total number of enterprises than these herds represent in the total inventory. About 60% of the nation's cow-calf enterprises have less than 20 brood cows. The remaining 40% manage more than 80% of the total cow herd (Gilliam 1984).

The types and costs of feed in the cow-calf operation reflect the location of the operation, the mix of native and seeded vegetation available within the operation, and the accessibility to other forage sources. Brood cows must

be fed year-round and feed is needed to maintain the calves until weaning or shortly thereafter when they are sold to stocker operations. Cow-calf operations normally rely on grazed forage as the primary feed source because of the relative low cost. Yet, grazing in the cow-calf operation comprises more than half of the total direct production cost (Gilliam 1984). Snow cover, drought, or poor nutritional quality during some seasons necessitate additional feed from harvested forages, such as hay or silage (Gee and Madsen 1988).

The amount of land used only for grazing (dry range and irrigated pasture) within cow-calf operations increases from eastern to western United States and as the size of the cow-calf operation increases (table 21). The importance of rangeland also increases from east to west, wherein 95% of the grazed forage is supplied from range and native pasture. In the western regions, 80% of the enterprises sell only beef cattle and less than 50% of the western operations sell any other crop, excluding hay (Gilliam 1984). Western cow-calf operations are primarily beef operations using predominantly range grazing as feed.

Small cow-calf operations generally use larger percentages of secondary sources of grazing, such as corn, grain sorghum, soybeans, and other cropland after the crops have been harvested (table 21). The relatively large acreage associated with crop residues in the North Central and Southern regions (table 21) reflects the fact that most cow-calf operations in these regions are supplemental enterprises located on farms primarily producing crops and other livestock products, such as hogs (Gilliam 1984). In some regions, crop residue grazing may represent the only forage available during that season (Gee and Madsen 1988). Thus, the significance of the feed sources is not apparent from the magnitude of feed supplied, but rather the availability of substitutes for that feed during that season.

The estimates of forage sources in table 21 do not include any public land or private grazing leased or rented. The implication of this additional feed source can be surmised in the forage diversity of western ranches where public land is more common. Ranches

Table 20.—Inventory of beef cows (1,000 head) by Assessment region in 1978 and 1986.

Region	1978		1986	
	Beef cow numbers	Percent of total	Beef cow numbers	Percent of total
California	966	2.5	1,305	3.2
Pacific North	986	2.5	1,240	3.0
Northern Rocky	10,153	26.1	11,479	28.1
Southwest	917	2.4	951	2.3
Northern	7,600	19.6	7,126	17.4
Southern	18,104	46.9	18,807	46.0
Alaska	NA	NA	4	T ¹
11 Western States	6,886	17.6	7,542	18.4
United States	38,726	100.0	40,912	100.0

¹Trace.

Source: 1978 data: USDA Economic Research Service (1979). 1986 data: U.S. Department of Agriculture (1987), *Agricultural Statistics*.

Table 21.—Acres per cow of various forage sources grazed within beef cow-calf farms and ranches, 1980.¹

Region and forage source	Cow herd size (head)			
	20-99	100-499	500 or more	All sizes
South ² :				
Annual pasture	0.14	0.18	0.15	0.15
Seeded perennial pasture	2.05	1.68	2.15	1.96
Native pasture	0.38	1.21	2.36	0.88
Hay aftermath	0.78	0.41	0.20	0.60
Crop residue	0.38	0.09	0.03	0.25
Total	3.73	3.57	4.89	3.84
North Central:				
Annual pasture	0.04	0	0	0.03
Seeded perennial pasture	1.53	2.20	3.90	1.75
Native pasture	1.05	0.33	1.56	0.90
Hay aftermath	0.26	0.61	0.18	0.34
Crop residue	0.20	0.58	0.23	0.28
Total	3.08	3.72	5.87	3.30
Great Plains:				
Irrigated pasture	0.03	0.01	T ³	0.02
Small grain pasture	0.01	0.02	0.40	0.07
Dry range	8.80	12.74	27.22	12.96
Hay aftermath	0.33	0.29	0.08	0.28
Crop residue	0.21	0.12	0.02	0.15
Total	9.38	13.18	27.72	13.48
West:				
Irrigated pasture	0.83	0.34	0.39	0.47
Small grain pasture	T	0	0	T
Dry range	15.08	18.59	23.93	19.34
Hay aftermath	0.80	0.54	0.53	0.60
Crop residue	0.04	0.05	T	0.03
Total	16.75	19.52	24.85	20.44

¹Excludes BLM and FS grazing, and grazing leased or rented from all other sources.

²These regions differ slightly from the Assessment regions: South here includes all states in Southern region except OK and TX; North Central here includes all states in Northern region except ME, NH, VT, MD, PN, NY, RI, MA, and northern parts of MI, MN, WI; Great Plains here includes ND, KS, OK, TX, the eastern parts of SD and NE, and the Front Range parts of CO, and NM; the Western region here includes all of the Western states except those parts in the Great Plains region.

³T = less than 0.005 acre.

Source: Gilliam (1984)

in the Great Plains are more dependent on dry (native) range than western ranches. Ranches in the West are more likely to have up to 5% of their feed source from irrigated pasture (table 21). The presence of hay aftermath as a grazing source indicates that these lands can be set aside for the production of hay. Western ranches had at least 2% of their lands in hay production and, in some size classes, as much as 5%. Great Plains ranchers had lesser amounts of hay production within each size class. The availability of federal or private-leased forage increases the ranches' flexibility in determining the total feed mix for the enterprise. Any change in this availability would require substantial changes in feed production.

Although additional forage production can be obtained by improvement, such as fertilization, a 1976 survey of cow-calf producers indicated that western range is rarely fertilized. During a 1981 survey, only 8% and 19% of native pasture in the SO and NO regions, respectively, were fertilized (Gilliam 1984). Fertilization rates on seeded pasture were much higher. Forage improve-

ment practices are implemented only when profitable. Recent economic factors have not encouraged the implementation of forage improvement practices, especially on rangeland (Pope and Wagstaff 1987a, Wilson et al. 1987). If the economic situation warranted, additional forage could be produced on the available land in every region by applying various improvement practices (tables 11 and 12).

Stocker Cattle

In 1986, stocker cattle were located primarily in the NO (36% of the total), SO (28%), and NR (27%) regions (table 22). Since 1978, stocker cattle inventories have declined less than 7% in the 11 western states. In contrast, a decline of over 3.8 million head, or 24%, was seen in the SO region. Stocker cattle numbers inventoried during the summer would show a shift from these January 1 numbers as cattle are usually bought for stocker operations in the winter and early spring and

Table 22.—Inventory of stocker cattle (1,000 head) in 1978 and 1986 by Assessment region.

Region	1978		1986	
	Stocker ¹ numbers	Percent of total	Stocker ² numbers	Percent of total
California	1,207	3.0	1,695	4.4
Pacific Northwest	924	2.2	1,016	2.6
Northern Rocky	10,602	26.0	10,214	26.6
Southwest	822	2.1	647	1.7
Northern	12,771	31.3	13,887	36.2
Southern	14,448	35.4	10,933	28.5
Alaska	NA	NA	T ³	T ³
11 Western States	6,483	16.0	6,078	15.8
United States	40,774	100.0	38,395	100.0

¹Includes steers and "other" nonreplacement heifers weighing 500 pounds and over, plus steers, heifers, and bulls weighing under 500 pounds, minus cattle and calves on feed.

²Includes "other" nonreplacement heifers, steers, and calves, minus cattle on feed. Does not include 2,000 cattle on feed reported in "Other States" in source.

³Trace.

Source: 1978 data: USDA Economic Research Service (1979). 1986 data: U.S. Department of Agriculture (1987), Agricultural Statistics.

moved to range and pasture for the growing season. However, the magnitude of these shifts would be small, and these January numbers show relative distribution of operations (table 22).

Stocker operations depend primarily on grazed forage as a feed source, but differ in the levels of management, capital inputs, and alternative feed sources. These production systems depend on starting weights of the calves, weights at marketing, length of feeding period, and kind of feed. One type of system purchases animals in late winter, pastures them for the summer, and sells them in the fall. The advantage of this system is the low cost of gain and the short feeding period which reduces price risk. This system involves less chance for large negative price margins than with other systems because the period the cattle are held by the operator is short, essentially just the growing season (Gee and Madsen 1988). Other systems purchase calves in the late fall and feed a ration of alfalfa hay or corn silage and small amounts of grain or other concentrates until grazed forage is available. These animals are held until spring or the following fall depending on cattle price fluctuations.

Two factors have encouraged increasing numbers of stocker operations to market cattle at heavier weights (Gee and Madsen 1988). Commercial feedlots have attempted to reduce feeding costs, increase the rate of turnover, and reduce price risks by beginning with heavier stocker cattle. Cow-calf producers have increasingly held calves after weaning to capture potential profits from additional growth and more benefits from herd improvement programs (Gee and Madsen 1988). In eight major cattle feeding states, the proportion of calves weighing less than 500 pounds in commercial feedlots in 1984 was only 52% of the proportion of lighter calves in the 1965 inventory (Gee and Madsen 1988). Heavier stocker cattle imply increased use of grazed forages and

further trends in this direction would imply an increased demand for grazed forages nation-wide.

Sheep Industry Structure

Like the cattle industry, the sheep industry can be divided into breeding herds and fed animal (lamb) production. Lamb feeding operations vary from 1,000 to 50,000 animals (Council for Agricultural Science and Technology 1982). In 1980, nearly 43% of the lamb crop was sold to commercial feedlots or packing houses for fattening (Gee and Madsen 1983). This percentage varies across regions in relation to the availability of lush forage. In the Pacific Coast, weaned lambs can be sold for immediate slaughter. However, in drier parts in the Great Plains area and in the Southwest region, few lambs are considered fat enough for slaughter and these lambs are often fed in drylot facilities or grazed on crop residues such as beet tops or alfalfa stubble. Thus, unlike stocker cattle operations, fed lamb operations are often part of the breeding operation, and more often depend upon crop residue than range grazing to produce the animal to be sold to the feedlot. The breeding operations demand the greatest amount of grazed roughages in sheep production.

Of the 115,000 sheep enterprises in 1985, nearly 92,000 were located in the 17 western states and the 7 North Central states (American Sheep Producers Council Inc. 1987).¹³ Characteristics of sheep operations vary with size and location. Nationally, 43% of producing ewes were in herds of 1,000 or more in 1978. Large herds (1,000 to 5,000 animals) were more common in the 17 western states (Gee and Madsen 1983). Farm flock

¹³North Central states of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio.

operations of less than 50 producing ewes are common in the midwestern and northeastern parts of the United States. A slight shift between 1969 and 1978 away from the medium-sized herds (100-199) to either herds of over 1,000 or less than 100 head may reflect the renewed interest in small farm flocks (Gee and Madsen 1983).

Important feed sources for sheep are public grazing and deeded nonirrigated pasture (table 18). In 1980, 1.8 million sheep grazed BLM-administered land and 1.3 million grazed on NFS lands, which represent 29% and 21%, respectively, of sheep in the western states. Since many operators use only one of these feed sources, these percentages may not represent the same sheep and 30% to 40% of all western sheep may rely on federal land (Gee and Madsen 1988). Operators may graze only part of their herd on public land, thus if all sheep within an enterprise are included, potentially more than 50% of sheep in the 17 western states are owned by enterprises affected by federal grazing land policies (Gee and Madsen 1988).

The large decrease in sheep inventories since the 1960s has significantly reduced the demand for grazed forage on traditional sheep ranges in the western United States. This grazing land has also been diverted to other uses, reducing the amount of federal land available for sheep grazing (Gee and Madsen 1983). Stable inventories since 1980 suggest that demand for forage will continue at the current levels.

Seasonal Dependency on Forage

The total feed mix for a livestock operation is a combination of many feed sources available at different times of the year. Sources, such as hay, are used to supplement unavailable or short supplies of feed. Seasonal availability of forage is a function of climate, management, land ownership patterns, and land use patterns. Management activities can mitigate the seasonal supply of forage by diversifying the type of plant species grown, such as extending warm-season pastures with the seeding of cool-season species in the South, or seeding warm-season species into the predominantly cool-season pastures in the North. In the western United States, livestock grazed public lands before these lands were managed as federal ownerships. These patterns of intermixing private with public grazing established a precedent for the historical dependency of grazing upon federal lands for at least part of the yearly forage needs (Bedell 1984).

When dependency is defined as AUMs of feed provided by public lands divided by total annual AUMs required by the entire livestock herd, the dependency level for cattle operations ranges from 11% to 60% across the 17 western states (USDA Forest Service and USDI Bureau of Land Management 1986). For sheep operations, the dependency levels range from 24% to 49%. In states such as New Mexico, livestock may graze federal land for the entire year, whereas in other states such as Montana, a seasonal use is more common.

The absolute magnitudes of these dependencies may not adequately reflect the potential changes in livestock operations if these seasonal sources of forage are changed. The actual impact will be a function of how the seasonally available sources interact with other sources of feed. For example, April, May, and June are critical feed months in eastern Oregon, and ranches with access to BLM grazing during this time can carry a larger herd in other months of the year (Bedell 1984).

Although ownership patterns contribute to seasonal dependencies, land use patterns also foster seasonal availabilities in forage sources. In southern Kansas, Oklahoma, and the Texas panhandle, wheat is planted in the fall, and with favorable moisture, the crop provides ideal winter pasture for several hundred thousand calves (Gee and Madsen 1988). Fields can be grazed under proper management from October or November to March, without harm to the wheat crop. The use of this stocker system varies with the annual changes in moisture, and, under dry conditions, very few cattle will be grazed on the wheat pastures (Herbel and Balten-sperger 1985).

TECHNOLOGICAL ENHANCEMENTS IN LIVESTOCK PRODUCTION

Technological Developments and their Influence on Livestock Production

The development and implementation of technology and its influence on animal production changed the use of forest and range vegetation (table 23). The introduction of cattle, horses, and sheep to North America changed the mix of grazers in forest and rangeland ecosystems. The development of refrigeration (1801), livestock shipment by rail (1852), and refrigerated railroad cars (1868) extended the distance from markets that livestock could be produced. As a result, vast areas of grazingland were opened in the interior of the United States. The development of the windmill (1854) improved the distribution of livestock across the landscape. Mechanical developments such as the hay baler and the grain elevator (1842) allowed forage harvested in years of good precipitation to be stored and used in drought (Smith 1979, Taylor 1984). The development of irrigation (1847) in the semi-arid west, and the introduction of improved forage species (1884 and 1888) diversified and nutritionally improved the feed mix and began to shift the use of land from grazing to cropping.

Technology has increased the type and quantity of outputs from the grazing animal. The introduction of exotic breeds (1817) and the development of growth stimulants (1949) have helped to increase meat or milk production per animal. Alternative livestock products such as angora (1849) diversified the grazing industry. The widespread implementation of artificial insemination (1939) and the development of drugs for estrous synchronization (1979) increased an operator's ability to genetically improve livestock production.

Table 23.—History of developments affecting rangeland management in the United States.

Year	Development
1636	First meat packing plant
1783	Improved cattle introduced to United States
1801	Refrigerator invented
1817	First Hereford and Jersey imported to United States
1834	Mechanical refrigeration developed
1836	First recorded auction sale of livestock in Ohio
1837	John Deere plows with steel share and smooth wrought iron moldboard
1842	First grain elevator in Buffalo, New York First rail shipment of milk
1843	Commercial fertilizer industry began
1847	Irrigation agriculture initiated in Utah
1849	Angora goats introduced to United States
1852	First livestock shipment by rail
1854	Windmill invented, Connecticut
1863	Dryland farming in Utah
1865	Chicago's Union Stockyards opened
1866	Goodnight and Loving trail cattle from Texas to Colorado and New Mexico
1867	First patent for barbed wire fencing, New York
1868	Refrigerated railroad car patented
1869	Transcontinental railroad completed Fresh meat successfully shipped from Chicago to Boston in refrigerated railroad cars; cooled by ice and salt
1874	Glidden barbed wire patent granted
1875	First continuous shipments of beef to England
1884	Smooth brome grass introduced
1886-87	Disaster in Great Plains cattle industry; winter storm, drought, overgrazing; this extends plowed agriculture into semi-arid and arid sections of United States
1888	Crested wheatgrass introduced from Russia
1888	Meat first shipped in railroad cars with mechanical refrigeration
1895	Commercial feed industry began in Chicago
1915	Refrigerated warehouse construction in meat packing plants
1927	Federal grading of beef initiated
1930	Range Livestock Research Station established at Miles City, Montana
1939	Artificial insemination widely used
1941	First performance bull testing station (Texas)
1942	Growth regulation property of 2,4-D discovered
1949	Usefulness of antibiotics in animal nutrition demonstrated
1950	Commercial feeding of stilbestrol to beef cattle began
1952	First successful breeding using frozen semen
1960	Cubing and wafering machines revolutionized hay handling
1960	Boxed beef processing began to influence industry
1978	First calf from a frozen embryo in the United States
1979	Diethylstilbestrol banned from use in cattle feeding
1979	First prostaglandin (Lutalyse) approved for use in estrous synchronization
1981	First test tube calf born in the United States
1982	First identical twin calves born in the United States as a result of microsurgery

Source: Smith (1979), Taylor (1984).

Increased feeding efficiency in animals has led to the doubling of market weights (Fontenot 1984). Live weight marketed per breeding female in beef cattle has gone from 220 pounds in 1925 to 317 in 1950 to 482 in 1975. Live weight marketed per breeding female of sheep has

risen from 59 pounds in 1925 to 90 in 1950 to 130 in 1975. Milk marketed per breeding female in dairy cattle has risen from 4,392 pounds in 1925 to 10,513 in 1975. One half the cow numbers are producing the same quantity of milk produced 30 years ago using one-third less feed (National Research Council, Board on Agriculture, Committee on a National Strategy for Biotechnology in Agriculture 1987).

Although many technologies have been developed to improve livestock production and the efficiency with which livestock harvest forage, the implementation of these technologies is lacking on rangelands (Lewis and Engle 1982). On the Great Plains, conventional barbed and woven wire are the most commonly used fencing technologies and solar-powered electric energizers are one of the least commonly implemented fencing technologies (table 24). Technologies to benefit both livestock and wildlife have had limited application. Antelope pass fencing is fully developed but has had little or no application (table 24).

Fed Beef Production

Fed beef are cattle that have been fed a fattening ration for the slaughter market. Stocker calves weighing from 500 to 750 pounds are purchased, fed a fattening ration for 4 months to 1 year, and sold at weights between 900 to 1,200 pounds (Nelson 1984). Little forage is used in this segment of the beef production, however this segment produces the final product and, thus, influences the supply and demand of meat.

At one time, all grain-fed beef cattle were produced on farms, and the major center of fed beef production was the Corn Belt states (Gee and Madsen 1988, Van Arsdall and Nelson 1983). In 1950, less than 40% of the cattle on feed were in the 17 western states. The development of irrigation, hybrid sorghum grains, and increased grain production in the Great Plains and West initiated shifts in the regional distribution of cattle feeding operations. Preceding and coincident with these agricultural developments were a number of discoveries related to beef nutrition and pest and disease control. These discoveries allowed for increased concentrations of cattle (Reimund et al. 1981). Commercial feedlots with a capacity of 16,000 head or more accounted for only 16% of the marketings in 1967, but by 1984, feedlots of this size had cornered 51% of all fed beef marketings (Gee and Madsen 1988). Whereas farmer-feedlots were vertically integrated with feed grain production and cattle feeding occurring during seasons when labor was not needed for crop production, these large commercial feedlots could separate grain production from livestock feeding, operate year-round, and reduce the seasonality of fed-beef production (Reimund et al. 1981). These technological advances coupled with the strong consumer demand for beef fueled the rapid expansion of cattle feeding during the 1960s and 1970s (Van Arsdall and Nelson 1983). In 1960, the proportion of the calf crop slaughtered as nonfed was 21%. By the early 1970s, this proportion dropped to 5% (Reimund et al. 1981). In

Table 24.—Status of development and application of facilities and equipment used to manage animals for managing and improving range ecosystems of the Great Plains.

Facility or equipment item ¹	Status of development ²	Extent of application ³
A. Fencing		
1. Conventional barbed or woven wire	3	3
2. Big game fencing	3	2
3. Suspension fencing	3	1
4. Electric, conventional	3	3
5. Electric, high efficiency	3	1
6. Solar-powered electric energizer	3	1
7. Mechanized fence builder	3	1
8. Antelope pass fencing	3	1
B. Water developments		
1. Improvement of natural supply	3	3
2. Wells, wind or power pumped	3	3
3. Deep wells	3	1
4. Reservoirs and dugouts	3	3
5. Rain catchments	3	1
6. Storage facilities	3	1
7. Piping	3	1
8. Heaters, propane	3	2
9. Heaters, solar-powered	2	1
C. Handling and animal management		
1. Corrals, related facilities	3	3
2. Portable corrals	3	1
3. Identification		
Fire branding equipment	3	3
Freeze branding equipment	3	2
Ear tags and bands	3	2
Electronic	1	1
Telemetered	3	2
4. Weighing		
Conventional scale	3	2
Electronic, automatic recording	1	1
5. Windbreaks, shelter, shades	3	2

¹Equipment and facilities are grouped according to their principal use. It is recognized that many have a variety of applications.

²Status of development:

1 = Undeveloped.

2 = Various stages of development, not available for general use.

3 = Fully developed and available for use; refinements may be made in existing equipment.

³Extent of optimum application:

1 = None or very limited.

2 = Significant, but incomplete.

3 = Complete or near complete.

Source: Lewis and Engle (1982).

1984, 76% of the cattle on feed were in the 17 western states (Gee and Madsen 1988).

Although fed beef production occurs in most states, the largest production is located in 13 states: Texas, Nebraska, Kansas, Colorado, South Dakota, Minnesota, Iowa, Illinois, Indiana, Ohio, Michigan, Arizona, and California. In the last 5 years, marketings declined in two of the leading cattle feeding states (Iowa and California). The trend toward more specialization, low returns from cattle feeding, and a greater emphasis on crop production in Iowa contributed to this reduction because feedlots are generally small and part of a diversified farming operation (Gee and Madsen 1988). In California, most feedlots are large commercial operations and their decline reflects declines in slaughter plant facili-

ties, the high costs of production associated partly with transportation of both cattle and feed into the state, and a reduction in the fed beef price premium enjoyed in past years (Gee and Madsen 1988). Fed beef marketings have been expanding fairly consistently in Colorado, Kansas, Nebraska, Texas, and Washington. The construction of new slaughter plant facilities, a surplus of feed grains, and plenty of easily accessible stocker cattle facilitates this expansion (Gee and Madsen 1988). In future years, cattle feeding will be concentrated more in the Central Plains with declines in the extreme Southwest and Cornbelt (Drabenstott and Duncan 1982, Gee and Madsen 1988).

Although the total costs are lower for large commercial feedlots, these operations are more sensitive to price

variations on inputs because nearly 99% of their total costs are variable costs. Commercial feedlots generally buy all their feed, whereas farmer feedlots are diversified operations in which all or a great proportion of the feed is produced on the farm (Van Arsdall and Nelson 1983). Variable costs were only 84% of the farmer feedlot total costs in 1979 (Drabenstott and Duncan 1982). Thus, shifts in the price of grain through rising exports, or changing government agricultural policies, affect fed beef production.

Future Technologies for Livestock Production

The future productivity of livestock could be increased by the development and implementation of 150 current and potential technologies (U.S. Congress, Office of Technology Assessment 1986b). These technologies span the entire spectrum of animal production from modifying and controlling the animal's environment to pest and disease control to manipulating and changing the animal's physiology (table 25). Many technologies currently exist to control pest and disease and to improve livestock reproduction rates. Genetic research has focused on altering livestock to improve reproductive performance, weight gain, disease resistance, or livestock coat characteristics (U.S. Congress, Office of Technology Assessment 1988). Enhancing the rate and efficiency of muscle growth to produce a leaner animal may be possible in the near future through the administration of recombinant hormones. Technologies currently exist

that can optimize tissue growth through the synchronization of nutrition with the animal's need for protein growth. Technologies are needed that allow more precise regulation of growth in animals and integrated growth management programs that will coordinate the application of these technologies in a holistic approach (National Research Council, Committee on Technological Options to Improve the Nutritional Attributes of Animal Products 1988).

The impact of these emerging technologies on animal production efficiency is expected to increase the pounds of meat per pound of feed from the actual 1982 value of 0.07 to 0.072 by 2000, and increase the number of calves per cow from the actual 1982 value of 0.88 to 1.0 in 2000 (U.S. Congress, Office of Technology Assessment 1986b). This indicates an annual increase of 0.2% in feed conversion efficiency and 0.7% in calving success.

The impact of these technologies on the forage demand from forest and rangelands is difficult to determine. Increases in feed efficiency will produce more meat per pound of feed, a distinct advantage in feedlots. Kalter and Tauer (1987) reported that the greatest near-term economic potential involves the use of bio-tech-created natural hormones in animal protein synthesis. Adoption of these technologies will result in improvements in feed efficiency, increased milk production, reductions in the total nutrient requirements for animals, and lower crop, land, and consumer prices. Land for grain and roughage production could decline 3.4 to 10 million acres (Kalter and Tauer 1987).

Table 25.—Emerging technologies for animal production and likely year of introduction under three future environments of technological development.

	Technology environments		
	More new technology ¹	Most likely ²	Less new technology ³
Genetic engineering:			
Production of pharmaceuticals	1982	1982	1982
Control of infectious diseases	1983	1983	1983
Improvements in animal production	1990	2000	>2000
Genetic abnormalities			
Detection	1990	1995	>2000
Treatment	1990	2000	>2000
Control of cancer and leukemia	1990	1990	>2000
Animal production:			
Cycle regulation	1985	1989	1995
Superovulation, embryo transfer, and embryo manipulations	1983	1983	1983
Improvement of fertility	1990	1995	1995
Genetic engineering techniques for farm animals	1995	2000	>2000
Regulation of growth and development:			
Muscle and adipose tissue accretion	1987	1992	>2000
Hormone, serum, and tissue factors important to growth	1995	2000	>2000
Immunological attraction of animals	1990	1995	>2000
Measuring body composition and animal identification	1990	1995	>2000

Table 25.—Continued

	Technology environments		
	More new technology ¹	Most likely ²	Less new technology ³
Animal nutrition:			
Animal production consumption and human health	1995	2000	> 2000
Alimentary tract microbiology and digestive physiology	1989	2000	> 2000
Voluntary feed intake and efficiency of animal production	1989	1995	> 2000
Maternal nutrition and progeny development	1984	1984	1984
Livestock pest control:			
Slow release insecticides	1984	1984	1984
Vaccines	1986	1986	1991
Integrated systems	1987	1989	1994
Modification of insect habitat	2000	2000	2000
Insect-resistant animals	2000	2000	2000
Utilizing immunity systems	1990	1990	1995
Disease control:			
Data management and systems analysis	1980	1980	1980
Diagnostic methodologies	1986	1986	1988
Selection for disease resistance	1994	1999	> 2000
Genetic engineering			
Embryos	1995	1999	> 2000
Micro-organism	1988	1989	1999
Immunobiology	1983	1983	1983
Environment and animal behavior:			
Energy conservation:			
Non-integrated system	1985	1990	2000
Integrated system	1995	2000	> 2000
Optimizing total stress	1995	2000	> 2000
Stress and immunity	1995	2000	> 2000
Photoregulation of physiological phenomena	1990	1990	> 2000
Utilization of crop residues and animal wastes:			
Energy from manure	1985	1985	1985
Energy from crop residues	1990	1990	> 2000
Animal feed from crop residue	1990	1990	> 2000
Animal feed from manure	1990	1995	> 2000
Monitoring and control technologies:			
Sensors, controllers, displays	1985	1985	1985
Communication and Information management:			
Networks, software, and database systems	1985	1985	1985
Manufacturing management systems	1987	1990	2000
Expert systems	1992	1995	2000
Telecommunications:			
Digital communication	1990	2000	> 2000
Fiber optics	1990	2000	> 2000
Videotex and teletext	1985	1985	1985
Value-added networks	1985	1985	1985
Integrated services digital network	1987	1990	2000
Remote sensing	1985	1985	1985

¹Assumes to year 2000: (1) a real growth rate in research and extension expenditures of 4%, and (2) all other factors more favorable than those of the most likely environment.

²Assumes to year 2000: (1) a real growth rate in research and extension expenditures of 2%, and (2) the continuation of all other forces that have shaped past development and adoption of technology.

³Assumes to year 2000: (1) no real growth rate in research and extension expenditures, and (2) all other factors less favorable than those of the most likely environment.

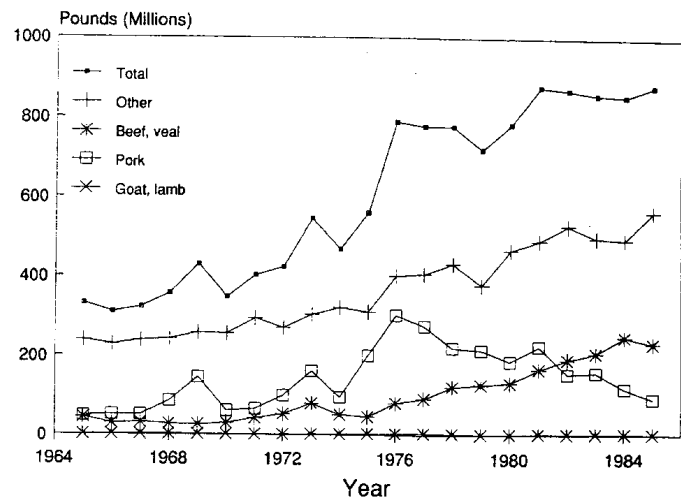
Source: After U.S. Congress Office of Technology Assessment (1986b).

DEMAND FOR MEAT

World Production and International Trade

The world meat output that enters international trade is only 7% of total world meat production. Bovine meat, which includes beef, had the largest share of the international meat trade; poultry has been the fastest growing segment (Food and Agriculture Organization 1983). The United States share of the international meat trade (bovine, sheep, poultry, and pork) was only 4.6% in 1980. By type of product, U.S. meat exports have increased (fig. 41), but these exports were less than 1.5% of total U.S. meat supplies in 1985 (U.S. Department of Agriculture [various years]). Lamb and mutton exports were 1% of sheep supplies in 1985. Pork exports were 1.6% of total pork supplies, a drop from the peak of 3.1% in 1976 (fig. 41). Beef exports have increased since 1970, but these exports were only 1.5% of the total beef supplies in the United States in 1985 (table 26).

World-wide agricultural exports during the 1970s reflected a combination of favorable factors: increased meat imports by the Soviet Union as it profited from higher oil and raw material prices, rapid income growth in developing countries used to improve diets, rapid export growth in developing countries, increased ability to borrow against oil supplies, and currency exchange rates, particularly the exchange rate of the U.S. dollar (Sanderson 1984). Countries such as the United States increased their share of the world meat exports by improved beef production technologies. The economic recession of the 1970s and higher meat prices in the early 1980s led to increased self-sufficiency rates for meat



NOTE:--Other includes sausage, bologna, variety meats, canned meat, and meat products.

Source: USDA (1965-1986)

Figure 41.—United States meat exports by type of product.

production (Food and Agriculture Organization 1983). Beef and veal production increased from 1961 to 1984 in Eastern Europe, USSR, North America, and Africa and Asia (fig. 42).

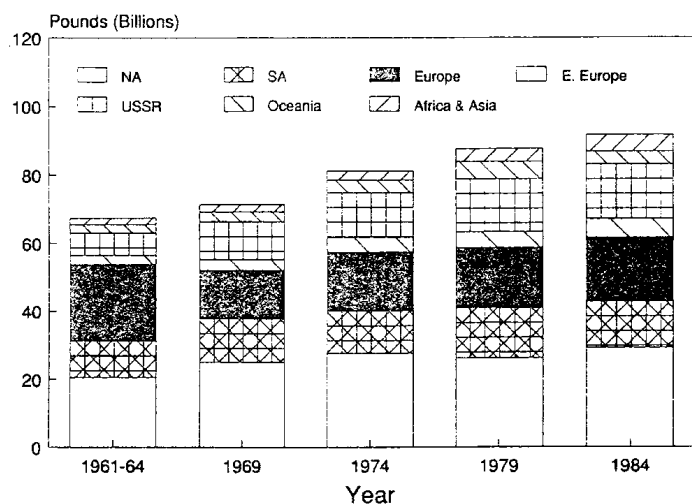
Depressed prices in the world meat trade were the result of a slack demand, continued rapid technological improvements in animal production, and protectionist policies (Food and Agriculture Organization 1983). Protectionist policies for the livestock sector have

Table 26.—Beef supply and foreign trade for United States, 1970-85.

Year	Supply (million pounds)			Percentage of total supply	
	Total	Imports	Exports and shipments	Imports	Exports and shipments
1970	23,830	1,792	101	7.5	0.4
1971	23,976	1,734	117	7.2	0.5
1972	24,739	1,960	114	7.9	0.5
1973	23,635	1,990	144	8.4	0.6
1974	25,200	1,615	115	6.4	0.5
1975	26,135	1,758	110	6.7	0.4
1976	28,392	2,073	158	7.3	0.6
1977	27,682	1,939	167	7.0	0.6
1978	26,854	2,297	214	8.6	0.8
1979	24,257	2,405	215	9.9	0.9
1980	24,057	2,064	220	8.6	0.9
1981	24,460	1,743	252	7.1	1.0
1982	24,732	1,939	305	7.8	1.2
1983	25,468	1,931	312	7.6	1.2
1984	25,746	1,823	376	7.1	1.5
1985	26,154	2,068	379	7.9	1.5

Note: Includes products converted to carcass weight equivalent. Edible offals are not part of the carcass and therefore not included.

Source: Gee and Madsen (1988). Data from USDA Economic Research Service, *Livestock and Meat Statistics 1983*, Statistical Bulletin 715, and *Food Consumption, Prices and Expenditures. 1985*. Statistical Bulletin 749.



NOTE.--Oceania = Australia, New Zealand, South Pacific Islands. NA, SA = North and South America.

Source: USDA (1961-1984)

Figure 42.—Annual beef and veal production by world regions, 1961-1984.

become more widespread, with approximately 25% of the total world meat exports heavily subsidized.

International beef and veal production will not soon see the expansive growth of the 1970s (Food and Agriculture Organization 1983). Rising demand from population growth or increased income levels in developing countries will stimulate meat production through intensive poultry and pig production, or rural and pasture-based ruminant production (beef, sheep, goats) in countries such as Asia, Africa and Latin America. Pig meat recently has replaced bovine meat as the principal meat worldwide, however the fast growth in poultry production may change that picture in the future (Food and Agriculture Organization 1983).

Projections by the Food and Agriculture Organization suggested that the world consumption of meat will grow only 1% a year in the 1980s, with the demand in bovine meat (beef) growing only 0.7% annually. Extending projections to 2000, Resources for the Future indicated an annual rate of increase in total demand (domestic plus net trade) for all meats to be 2.4% globally over the 1980-2000 period, a drop from the 3.1% increase during 1969-80 (Sanderson 1984). The implication to international meat trade is a slow growth overall or decline in growth for some meat products (Food and Agriculture Organization 1983). Many developing countries are moving toward self-sufficiency in poultry and pig production. Trade in meat from ruminant animals may increase in the Near East and North Africa, but favoring neighboring suppliers in Asia and East Africa (Food and Agriculture Organization 1983). The implication to the United States meat industries is that there is little likelihood of the international trade improving over the next 20 years (Sanderson 1984). Thus, demand for meat in the United States will be primarily a function of domestic demands.

Consumer Demand for Meat in the United States

Meat Consumption

Total per capita meat consumption increased slightly from 1965 to 1985 (fig. 43). Beef surpassed pork consumption in 1953 (Nalivka et al. 1986) and steadily increased to a peak of 89 pounds per capita (edible weight¹⁴) in 1976 (fig. 43). Thereafter, beef consumption declined to a low of 76.5 pounds in 1980 and has since remained below 80 pounds. Lamb and mutton consumption was greater than 3 pounds per capita before 1960 (Stucker and Parham 1984). Consumption declined from 2.6 pounds (edible weight) in 1970 to 1.1 pounds by 1986, a very small amount compared with a total beef, veal, pork, lamb and mutton per capita consumption of 120.5 pounds.

The largest increases in per capita consumption were associated with poultry and fish (fig. 43). Consumption of chicken rose from 23 pounds in 1965 to 39.7 pounds (edible weight) in 1985. Turkey consumption nearly doubled in the same time period (USDA Economic Research Service 1986). The advances in harvesting technology increased the accessibility of fresh fish, and consumption rose from 10.8 pounds in 1965 to 14.5 pounds in 1985. Indications are that fish consumption will continue to increase (Blaylock and Smallwood 1986).

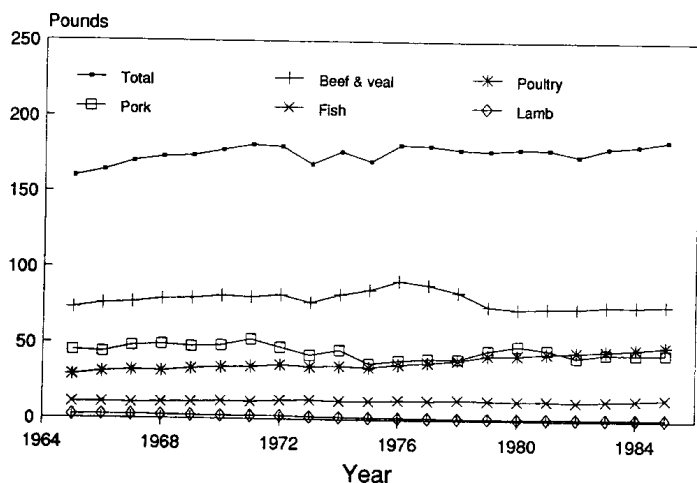
Studies on the composition of food supply in the United States have indicated a rise in the consumption of low-fat animal products, such as low-fat milk and fish, but an increase in the use of high-fat food such as hard processed cheese and baking and frying fats of both vegetable and animal origin. Dietary survey data and supermarket sales suggested that the fastest growing food items were meat mixtures, where meat, poultry, or fish are mixed with grains or pasta (National Research Council, Committee on Technological Options to Improve the Nutritional Attributes of Animal Products 1988).

Population Size and Age Distribution

Population growth alone increases the total consumption of meat. The population growth rate in the United States peaked in 1950-55 at 2.1% annually. Growth during the 1970s was 1.1% annually. Future increases in population growth are estimated to decline from annual rates of 1.0% to 0.2% by 2040 (Darr in press).

Changes in the age class distribution with the overall increase in the median age will affect the per capita consumption of meat. The age class distribution is shifting to middle and older groups, and older persons are not inclined to consume as much meat as younger individuals (Blaylock and Smallwood 1986). Food spending patterns differ across age classes also. Younger individuals are forming eating patterns relying on fast

¹⁴Edible weight is used in comparing meat consumption across type of eat. Edible weight (beef) = 0.698 times (carcass weight) (USDA Economic Research Service 1986).



Source: USDA, Economic Research Service (1986)

Figure 43.—Per capita meat consumption in the United States by edible weight.

food, more purchases away from home, and preferences for the lower priced cuts or even less meat consumption (Blaylock and Myers 1987, Gee and Madsen 1988). Regional differences in meat purchases tend to be small (Blaylock and Myers 1987).

Disposable Personal Income

Food competes for the consumer's dollar against non-food items such as housing, clothes, cars, and recreation. Thus, the total budget allocation process must be analyzed in explaining meat consumption behavior (Haidacher et al. 1982). Studies in consumer spending patterns indicate that disposable income has significantly affected consumer spending patterns worldwide. Where disposable income is low, cereals make up a major portion of the diet. With increasing income, a wider variety of foods, including more meat, are eaten (Blaylock and Smallwood 1986, Food and Agriculture Organization 1983). Per capita disposable income in the United States has been higher than other parts of the world, and the high percentage of meat and poultry in the average American diet (over 33%) reflects this economic situation.

In the United States, consumption patterns are being established under a situation of rising nonfood costs and an availability of cheap food. As food costs as a whole increase, consumers tend to consume lower cost food products. Because beef is a major component of the food purchased and is relatively expensive, the amount of beef purchased tends to be reduced before that of many other foods when income is reduced (Gee and Madsen 1988). Before 1980, rising per capita disposable income levels were associated with rising per capita meat consumption. After 1980, per capita disposable income has continued to rise but the percentage spent on beef has declined. Per capita disposable income (1982 constant dollars) has increased from \$9,829 in 1980 to \$10,947

in 1986, whereas the percent spent on beef has fallen continuously from 2.4% in 1979 to 1.5% in 1986.

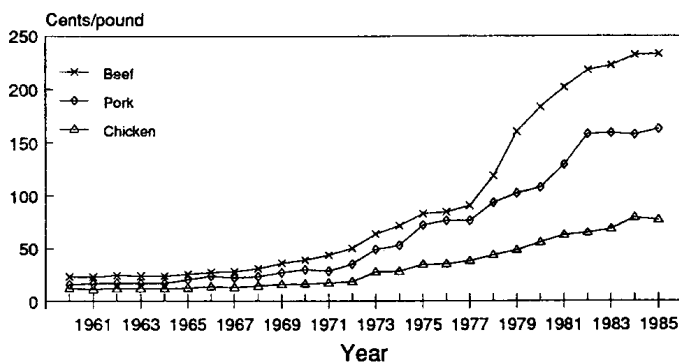
When individual income groups are analyzed, increases in meat consumption are still occurring within lower income groups, but the increases are not great in higher income groups. Thus, changes in the distribution of incomes will change the consumption of meat more than an increase in the average per capita income across the nation (Buse 1986).

Prices and Marketing Strategies

The cause for recent shifts and declines in per capita meat consumption is uncertain. Changes in sociological factors such as a more health conscious public or taste preferences, or changes in economic factors such as increased disposable income have been suggested as reasons for the shifts in consumer demand (Breidenstein 1988, Doane's Agricultural Report 1987, Drabenstott and Duncan 1982, Greenhouse 1986, Walter 1985). The hypotheses require numerous observations before these factors can be quantified econometrically (Crom 1984) and many studies have been and are being conducted to determine if structural changes have occurred in the demand for meat (Braschler 1983, Chavas 1983, Conway et al. 1987, Dahlgran 1987, Haidacher et al. 1982, Kokoski 1986, Moschini and Meilke 1984, Wohlgenant 1985).

Record high levels of meat production have placed a large and diverse amount of meat in the supermarket case. Beef demand is impacted by the availability of substitute products at lower prices than beef (Greenhouse 1986). Cost efficiencies resulting from the integration of production and processing activities have given a competitive advantage to poultry production that beef and lamb producers have not enjoyed. Not only is the conversion of feed more efficient in poultry than in cattle, but improved production technologies such as disease control, feeding practices, and confinement housing have allowed poultry production to maintain lower prices than beef (fig. 44). In the absence of such technologies, the retail price for chicken would have been 175% higher than the actual price in 1983 (Lipton 1986). In 1960, beef prices were twice chicken prices and by 1986 had risen to over three times chicken prices (fig. 44).

The continued ability of retailers to maintain profit from beef reflects their great buying power (many different packers) and the diversity of meat products available. When beef prices rise, retailers can offer the lower-priced meat products, such as poultry, to satisfy consumer demand (Gee and Madsen 1988). Packers and processors have developed brand lines of meat to reduce the ease with which a retailer can switch to alternative suppliers and have increased promotion efforts toward consumers to reduce the attractiveness of substituting other meats for beef. Although the results of these efforts will not be known for some time (Cohn et al. 1987), it is clear that meat production and marketing is highly competitive.



NOTE.—In 1985 \$ (GNP price deflator 1982=100).

Source: Crawford (1988)

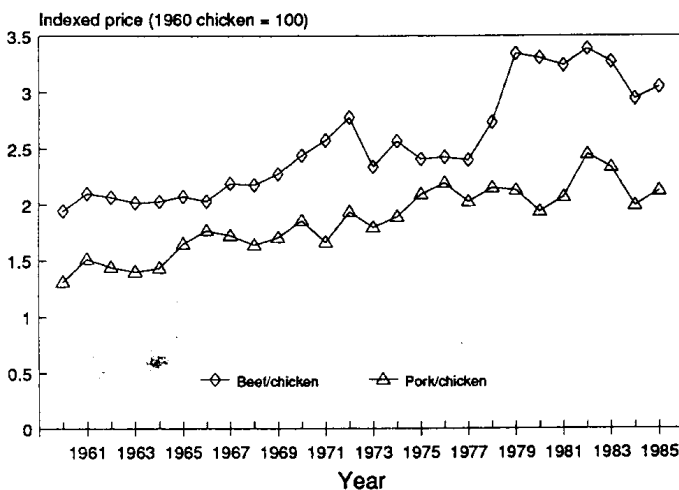


Figure 44.—Retail and indexed prices for whole chickens, pork, and choice beef, 1960-1985.

New product development in the meat industry has been spurred by the changes taking place in society. Working couples and single heads of households are attracted to convenience foods with short preparation time. In addition, increased amounts of food are being consumed away from home. In 1962, 28% of total food expenditures were spent eating away from home, and by 1985, the percentage had risen to 43%; fast food outlets cornered an increasing share of food expenditures (Lipton 1986). Concern about nutrition and health have raised additional issues about diet. Demographic changes in the population also are spurring new product development.

New poultry products developed to meet the changing wants and needs of consumers have helped to maintain the high demand for poultry. In the 1950s, shoppers would likely have purchased a store-labeled whole chicken. In the 1980s, consumers can select from various brand-name chickens, whole or cut-up chicken, boneless chicken or chunks, or pre-cooked items, such as barbecue turkey (Lipton 1986). Higher production costs have limited the new product development in the

pork industry, although many new pork products have been developed (Gee and Madsen 1988). The relatively high consumer demand that beef has enjoyed for nearly 30 years has not exerted much pressure for new product development.

Boxed beef represents the last major innovation in the beef industry (Gee and Madsen 1988). Before this development 20 years ago, beef left the packer as sections of the animal, forequarters and hindquarters. Now beef is cut up into smaller portions called primal or sub-primal cuts, sealed in vacuum-pack bags, and shipped out in cardboard boxes, hence the name boxed beef. In 1979, total packer boxed beef was 50% of fed cattle marketings, but by 1984, had increased to 77% (Gee and Madsen 1988). With the development of boxed beef, the slaughtering and packing of animals became assembly-line tasks and the average number of carcasses handled increased from 125 to 400 a day (Greenhouse 1986). But this innovation, a major step in increased efficiency of beef production, did not alter the end product provided to consumers.

Recently developed beef products have included prepackaged meat portions, precooked products, boneless cuts, and shredded beef with sauces (Gee and Madsen 1988, Greenhouse 1986). Perhaps the most encouraging recent development is the ability to restructure beef into fabricated steaks from high quality trimmings, much like the fabricated crabmeat now available (Gee and Madsen 1988). The beef fabrication process, developed at Colorado State University (Best 1986), would allow for uniform construction and fat content of each cut. The resultant product appears like a steak cut from the side of an animal. The Food and Drug Administration and the U.S. Department of Agriculture must approve the process before it can be used on a commercial basis.

Another production and marketing strategy being developed within the beef industry is the use of brand names, similar to brand development in chicken. This development is occurring for larger packing companies, for smaller livestock operations, and in Europe as well as in the United States (Geoghegan 1987, Greenhouse 1986, Howard 1987). Characteristics promoted include low fat, low cholesterol, production free from unsafe residues or chemicals, and taste (Greenhouse 1986, Howard 1987, Jackson 1985). In addition, the benefits of wild game meat are also being promoted as low in fat and cholesterol (Sheram 1986).

Projecting Meat Demand and Implications for Forage Demand

Short term projections indicate that demand for meat will be steady or will slowly rise (Walter 1985). Sander-son (1984), reporting on projections compiled by Resources for the Future, indicated a 0.9% growth in the total demand for meat (primarily domestic demand) in the United States, similar to the projected future population growth (Darr in press). This total demand for meat is less than the 1.4% annual increase witnessed during the 1970s. A work group consensus, at the Future

Agricultural Technology and Resource Conservation symposium (Smith 1984), was that beef per capita consumption would increase only slightly from 1984 to 2030 (table 27). This slow increase in per capita consumption suggests that increased demand for meat production will be primarily a function of population growth. The meat and beef industries have been characterized as "mature" industries, and growth in demand for mature industries is dependent entirely upon population growth (Fedkiw 1987).

In assessing the likely future trends in food consumption, Blaylock and Smallwood (1986) suggested that food groups likely to increase most were food away from home, fish, fresh fruits, and alcoholic beverages. Less than 40% of the total beef purchases are made away from home (Baker and Duewer 1983, Buse 1986). Beef is a small percentage of food purchased at restaurants and a much larger percent of food purchased for home (Thurman 1986). Thus, increases in beef seen as a result of increases in food purchases away from home will be smaller.

The cause for recent shifts and declines in per capita meat consumption is uncertain. Changes in sociological factors such as a more health conscious public, or economic factors such as record high levels of meat production will require a few years of data before shifts in consumer demand are quantified. For this assessment, population and income projections will be used to determine the future demand for meat production.

Forage demand could be greater if the lean beef production required only forage to finish animals. The recent trends are for a shorter period in the feedlot and not necessarily a longer period on grass. This would imply less grain demand rather than an increased forage demand. If per capita beef consumption increased and the increase was toward lean meat, then the forage demand would be greater to meet increased production of beef and lamb meat.

FORAGE AS AN INPUT TO ENERGY PRODUCTION

Projections made in the present assessment are based on the assumption that historical trends will continue to shape the future supply/demand and that changes in resource demand and land use will be an outgrowth of these trends and not abrupt discontinuities from the past. The possibility exists for a significant departure from historical trends. Two events that may dramatically alter the future management and use of forage resources are climatic change (Chapter 2) and the development of an energy industry using forage biomass as a feedstock.

Technological barriers and a significant drop in oil prices decreased the interest in biofuels generated during the 1970s oil crisis. Renewed interest will depend on (1) the cost and availability of oil, (2) the potential for replacing oil with coal, (3) developments in biomass conversion technologies, and (4) the availability of biomass (Byington 1988). Uncertainty exists within each of these areas. Adequate oil supplies are expected for another 30 years, although political factors and the desire to remain energy independent could raise oil prices through import duties and taxes (Byington 1988). Coal's high energy content per volume, concentration in major deposits, and vast reserves are balanced by high conversion costs and environmental considerations.

The advantages of biomass as an energy source are that biomass is a renewable resource, and converts with relatively few adverse environmental impacts when perennial vegetation is used. Limitations on biomass utilization are that it is a highly dispersed resource, is bulky, and has a relatively high water content. Although the conversion of biomass to ethanol has the advantage in that the end product is a usable energy product, the current economic feasibility of forage as a biofuel is still lacking (Byington 1988).

Byington (1988) presented a scenario regarding the future of biofuels and forage resources. Spurred by issues

Table 27.—Per capita consumption (pounds per person) in 1984, and estimated for 2000, and 2030.

Item	1984		2000		2030	
	Retail wt.	Carcass wt.	Retail wt.	Carcass wt.	Retail wt.	Carcass wt.
Beef	77	104	80	108	80	108
Veal	2	2	2	2	2	2
Pork	60	65	60	65	60	65
Lamb	2	3	2	3	2	3
Dairy products		540		520		510
Chicken						
broilers		49		55		55
mature chickens		3		3		3
Turkey		11		13		15
Eggs		36		33		30
Fish		13		18		27

Source: Smith (1984).

such as balance of payments, national security, idle cropland, and environmental concerns about climate change, the development of a forage biofuel industry is given government incentives such as: (1) laws mandating biofuel use, particularly in urban areas for environmental reasons, (2) government vehicle fleet use of biofuels, (3) tax breaks, (4) low-cost financing, (5) technical assistance, (6) price supports, and (7) increasing fossil fuel prices through taxes. Oil reserves are depleted in 30 years, and liquid fuels from coal become the least expensive fuel source. Biofuel development continues and eventually environmental concerns about coal and possible economic advantages over coal shift energy use to biofuels.

Under this scenario, a biofuels industry based on forage could create a new demand for land producing herbaceous material. The short-term impact on forage-producing lands will be marginal as cropland is used to supply this new demand. The long-term impact could be significant as cropland shifts back into crop production and an expanding beef herd and biofuel industry cause an intensification of management on pasture lands. Higher returns would shift land use from forage to biofuel production; livestock grazing would be eliminated on productive pasture and grazing lands where haying is possible. Substantial pasture and rangeland area in the South could be taken out of livestock production. Specific needs in regional livestock industries, such as supplemental feed in the northern regions, or land use patterns where only small blocks of hayland are available, would restrict the conversion of all grazinglands to biofuel production (Byington 1988). Grazing would remain on forested land in the South, range and pasture lands in the West, and land with no cropland conversion potential. Byington (1988) concluded that adequate forage supplies for livestock in 2040 would become unlikely if an expanded demand for cropland or forages developed.

SUMMARY

Forage is an intermediate good to the production of the final output, such as wildlife, livestock, wild horses and burros. The demand for the final output, the herbivore, can be used to derive the future demand for range forage. The demand for livestock is a function of society's demand for market commodities such as meat, hides, wool, tallow, and secondary products. The most significant demand for livestock is meat.

The demand for meat is a function of export demand and United States consumption. United States meat exports were less than 1.5% of the total meat supplies in 1985. The international meat trade is projected to grow slowly, with many countries seeking self-sufficiency in meat production. The implication is that the demand for meat in the United States will be primarily a function of domestic consumption. The domestic demand for beef or lamb meat is related to consumer tastes and preferences, disposable income, changes in human population size and age distribution, and the relative prices of alternative foods, particularly other meats.

The cause for recent shifts and declines in per capita meat consumption is uncertain. Changes in sociological factors such as a more health conscious public, or economic factors such as record high levels of meat production will require a few years of data before shifts in consumer demand are quantified. Population and income projections will determine the future demand for meat production.

The supply of meat is determined by the cost structure of production. The price of beef cattle or sheep depends upon the interactions between the supply and the demand of meat. The forage demand for livestock production depends on the technology associated with livestock production, the prices of alternative feeds, the interactions of forage with other inputs, and the price of livestock. The availability of grazed forages is critical in two segments of the beef cattle industry: breeding herds and stocker cattle production. For the sheep industry, the breeding herds are dependent upon grazed roughages.

Grazed forage consumed by beef cattle and sheep is produced on deeded nonirrigated rangeland and pasture, publicly-owned grazing land, deeded irrigated pasture, and from crop residue. The relative contribution of each forage source reflects the type of operation, type of animal, and the regional land use. Public grazing is more important in the West, whereas crop residue is more important in the East.

Forage demand could be greater if the lean beef production required only forage to finish animals. The recent trends are for a shorter period in the feedlot, which would imply less grain demand, rather than an increased forage demand. If per capita beef consumption increased and the increase was toward lean meat, then the forage demand would be greater to meet the increased production of beef and lamb meat.

CHAPTER 4: FORAGE SUPPLY/DEMAND PROJECTIONS

For the present assessment, forage supply was projected from the future availability of grazingland and likely improvements in forage production. Demand for grazed roughages was determined from future livestock projections, and assumptions concerning the future distribution of forage sources. Many of the aspects about the production and consumption of forage prohibit a traditional market equilibrium model at the national level (as is used for timber). Factors affecting supply and demand of forage are often local and reflect an individual livestock enterprise (Chapters 2 and 3).

The supply/demand of livestock has been simulated in econometric models where livestock production interacts with other agricultural commodities (Boss et al. 1978). The projection horizon is a function of factors included in the model that determine the supply/demand of livestock. When meat production is represented by changes in livestock inventories and animal prices, the model is often used to project for short periods of time, 1 to 10 years. Long-term issues, such as the impact of land availability, technological improvement in the forage production, and the effect of this improvement on inventories of livestock, can not be examined in many of these short-term projection models (Salathe et al. 1982, Taylor and Beattie 1982). The National Interregional Resource and Agricultural Production model (NIRAP) analyzes meat production as a function of feed inputs aggregated at the national level (Quinby in press). By incorporating some aspects of the livestock production process, this model provides a long-term projection for meat production and has been used in previous assessments and appraisals (USDA Forest Service 1980, USDA Soil Conservation Service 1987c). The NIRAP model was used to project the national demand for meat and livestock production for the present assessment.

All projections of the future rest on a set of assumptions concerning the demographic and economic variables within society. The basic assumptions for the Range Assessment projections are presented in this chapter, followed by the supply and demand projections for forage.

BASIC ASSUMPTIONS

Population

In 1986, the United States population was 242 million, an increase of 100 million in the previous five decades. Over the next five decades, population growth will be slower than in the last 50 years, and the population is projected to reach 333 million by 2040. The decline in the annual growth rate, from about 1.1% in the 1970s to 0.2% in the 2030-2040 decade, reflects

assumptions about declining fertility rates (Darr in press). These population projections assume a net immigration of 750,000 people per year, including an estimate for net illegal immigration.

The distribution of population growth will influence the demands and services needed within states and regions. The most rapid growth will occur in the Pacific Coast, the Southern, and some areas within the Rocky Mountain region. The age distribution of the United States population will shift during the projection period to a greater proportion of the population in the middle-age classes.

Per Capita Disposable Income

Disposable personal income is that income available for spending or saving. As such, this income is related to the general economic picture often described by the gross national product (GNP). In 1986, the GNP was more than five times the 1929 level. Analyses by Wharton Econometric Forecasting Associates indicated that by 2040, GNP will increase over four times that of the 1985 level (Darr in press). Within this economic environment, by 2040 disposable personal income will increase some 2.5 times the level of 1986 (Darr in press). This increase in per capita income implies that future populations will have a much greater purchasing power than today. Although this is critical in terms of the consumption of goods and services, the link between disposable personal income and the consumption of meat, as discussed in Chapter 3, has weakened. Increased personal income will also have impacts on other uses of the range resources, such as recreation.

Energy

The economic projections assume that while transportation, trade, and other services will grow slowly in terms of their share of the total economic activity, the United States will continue to produce large quantities of physical goods in the manufacturing and construction sectors. Thus large supplies of energy, minerals, and other raw materials will be needed to produce these goods. Oil prices (in constant 1982 dollars) rise from \$12 per barrel in 1986 to \$50 in 2020 and remain at this level through 2040 (Darr in press). For this assessment, conservation and development of alternative energy sources slow the rate of increase in energy prices. The 2020-2040 prices are assumed to be high enough to stimulate the development of alternative energy sources with implications for the demand for timber and timber products, especially fuelwood. For forages, government intervention is

assumed necessary to foster an energy industry utilizing forages as an input to energy production (Byington 1988). Thus, the development of alternative energy sources is not assumed to shift the demand for forages.

Institutional and Technological Change

Institutional changes, such as legislation for the reservation of land for wilderness, parks, and wildlife refuges, have occurred in the past, and have changed the use of rangelands (fig. 23). Legislation has affected the management of rangelands in terms of providing forage and habitat for wild horses and burros, endangered or threatened plant or animal species, and wildlife (table 13). Technological changes have also impacted the production of forage (tables 11, 12, and 23). These institutional and technological changes are assumed to continue in the future and the effects of these changes will likely be similar to those that have occurred in the past. Many of these changes are implicit in the historical data used in preparing the projections. Other assumptions are explicitly described in the analysis.

Productivity within the Agricultural Sector

Productivity of the agricultural sector is expected to grow at 1.6% per year, with increased productivity of feed grains averaging 1.7% in 1990-2000 and 1.2% in 2000-30 (Quinby 1985). Increased productivity of rangeland is projected to grow at 0.7% per year (Pendleton and Hetzel 1983). This increase is based on the assumption that rangeland productivity would grow at this rate if the currently available technologies were implemented on the Nation's rangeland. Technology currently available to increase rangeland productivity includes undesirable plant and insect control, interseeding, fertilization, and improved animal management through grazing systems and fencing (tables 11, 12, 24, and 25). The factor most severely limiting increased productivity on rangelands is capital investments, including short-term investments for maintenance of productivity. Under an unfavorable economic situation, this annual increase could drop to 0.3%. A high demand for range products could increase the price received for those products. This return would enable and encourage the producer to make greater than expected capital investments in range improvements such that the annual increase could rise to 1.2% (Pendleton and Hetzel 1983). For this assessment, the median estimate was used to project likely future increases in forage production. This projection does not include the likely increases in beef and lamb productivity (table 25), nor does it include additional developments not currently available for forage production (table 12).

Trade Assumptions

A number of studies have projected that future world agricultural trade will likely grow more than in 1982-83

but less than in the boom years of the 1970s (Food and Agriculture Organization 1983, Quinby 1985, Sanderson 1984). Several factors will limit exports: increased production in foreign importing countries, debt problems in many developing countries, volatility in currency exchange rates, and less than robust foreign economic growth. For this assessment, United States export growth is expected to grow 3% per year in the 1990s and 2% over the following decade; the strongest growth will be in the export demand for feed grains (Quinby 1985).

Rising demand from population growth or increased income levels will stimulate meat production worldwide. The demand for this meat, however, will be met with intensive poultry and pig production, or rural and pasture-based ruminant production within each country. The implication to the United States meat industries is that the international trade in meat will probably not improve over the short-term. The demand for meat in the United States will be primarily a function of domestic demands, not rising exports.

Beef, Veal, Lamb, and Mutton Consumption

In 1950, per capita pork consumption was 64.4 pounds, beef and veal, 57.4 pounds, and poultry, 24.7 pounds (Lipton 1986). Thirty-five years later, beef and veal consumption (edible weight) was more than 80 pounds, poultry, 69 pounds; and pork, 62 pounds (fig. 43). By 1985, total meat consumption had risen 165% from 1950 levels (Lipton 1986). This rise in total meat consumption, primarily beef, was the basis for projections in the early 1980s that beef, veal, lamb, and mutton consumption would rise 11% by 2030 (USDA Forest Service 1980). Increases in meat consumption did not continue into the 1980s and by 1987, per capita meat consumption (beef, veal, lamb, mutton) had dropped below the high levels seen in the 1970's (fig. 43). Future projections suggested only a rise from 108 pounds in 1982 to 111 pounds (carcass weight) by 2030 (table 27) (USDA Soil Conservation Service 1987c). For this assessment, per capita consumption of beef and veal is assumed to remain at 110 pounds (carcass weight) and lamb and mutton at 2 pounds (carcass weight) in 1987-2040 (fig. 45).

DERIVED DEMAND FOR FORAGE

The demand for forage is a function of the demand for beef cattle and sheep. Incorporating the assumptions outlined above, supply/demand projections for beef, veal, lamb, and mutton were made with the NIRAP model. Factors affecting the demand for meat include future population levels, per capita food demands including meat, and net exports. Factors affecting the supply of meat include increases in crop productivity, feed grain production, and prices paid by farmers. An equilibrium solution of price-quantity combinations of agricultural products including meat was determined by the NIRAP model (Quinby 1987, Miranowski 1988). A national

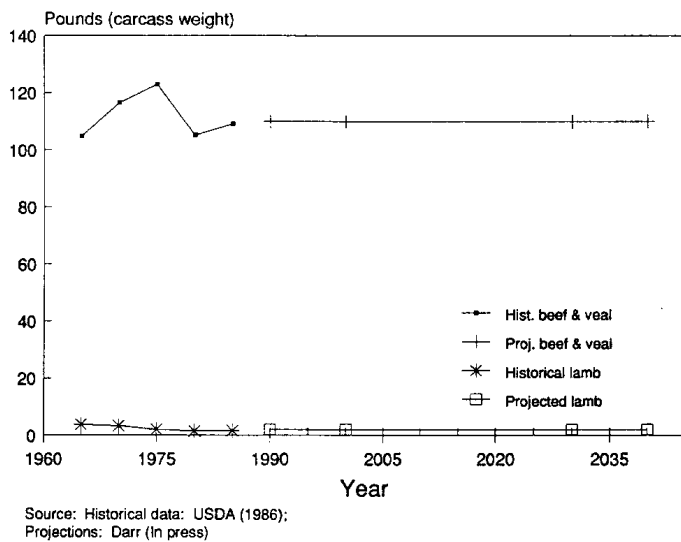


Figure 45.—Per capita consumption of beef, veal, and lamb: historical and projected, 1965-2040.

feed/meat production relation is used in the NIRAP model to calculate livestock production. The regional relations between forage sources, availability of land, and factors in forage production are not examined in the NIRAP model and for this assessment, projections of meat production from the NIRAP model were disaggregated to the regional level based on historical distributions of livestock (Chapter 3). The derived demand for forage, based on regional historical patterns of grazed forage consumption, was then determined.

Meat Projections

Beef and veal production is projected to increase throughout the projection period and by 2040 will be 56% above the 1985 levels (fig. 46). This increase in beef and veal production reflects the 39% increase in population, the 260% increase in per capita disposable personal income, a 4% increase in meat exports, and a 2% decrease in meat import (resulting in a greater demand on domestic production) over the projection period. The 1985 base year value for per capita consumption of beef and veal was 109.1 pounds, thus per capita consumption rose slightly over the projection period. This per capita rise and population growth resulted in a 147% rise in the demand for meat. The effect of per capita disposable income on meat consumption is less than during the 1970s, but the significant rise in per capita income in the last projection period results in beef consumption slightly above 110 pounds. Even with these projected increases, beef and veal production do not exceed historical production values until 2000 (fig. 46).

Lamb and mutton production is a small component of the total meat production in the United States and as such, is difficult to project with any certainty. Projections from the NIRAP model suggest a very optimistic picture for lamb and mutton production with increases

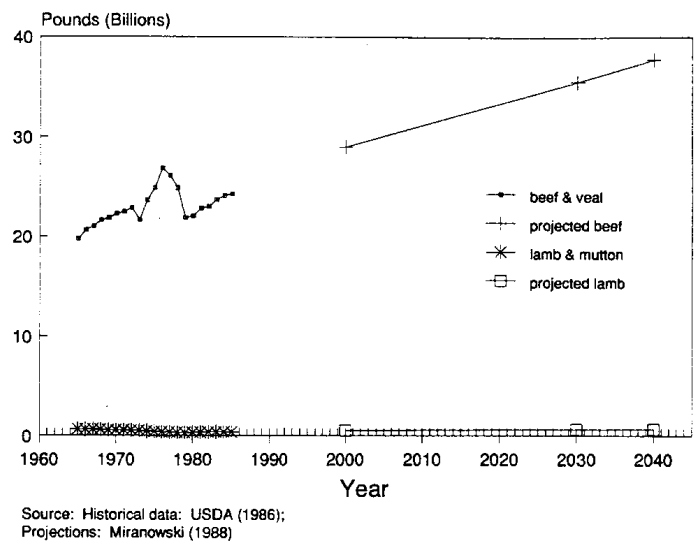


Figure 46.—U.S. meat production by animal type (carcass weight): historical (1965-1985) and projected (2000-2040).

of 85% over the projection period to 660 million pounds by 2040 (fig. 46). Actual production for 1985 was 357 million pounds (U.S. Department of Agriculture 1986). Sheep inventories and lamb and mutton consumption records suggest an historical decline and a recent flat trend in consumption (figs. 34 and 43). The variability of historical levels of sheep were used to bound the optimistic projection.

Livestock Inventory Projections

The NIRAP meat projections (fig. 46) were used to estimate future livestock inventories (Gee and Madsen 1988). The historical variability in livestock inventories in 1965-86 reflects technological and social changes in meat and livestock production, including cattle cycles. The assumption is made that these factors will continue to influence livestock production to the same extent in the future. The certainty with which a projection can be made decreases in time, thus the upper and lower limits for the projections of livestock inventories were computed using 1 standard deviation from the mean for 1990, and 3 standard deviations for 2030 and 2040 (Gee and Madsen 1988).

Beef cow inventories in 2040 are projected to be 55 million, a 56% increase over 1985 inventories (fig. 47). Beef cow numbers are not expected to exceed the historical peak until after 2000, and the 2040 inventory is only 21% above the 1975 peak. Based on the historical variability in livestock inventories, the upper bound for the 2040 projection was 64.5 million beef cows and the lower bound, 45.6 million cows. Given recent trends in per capita consumption of meat, an aging human population, a flat export demand, and competitive substitutes for beef, it is unlikely that the beef cow inventories will move toward the upper bound, and more likely these inventories will be between the projected and lower

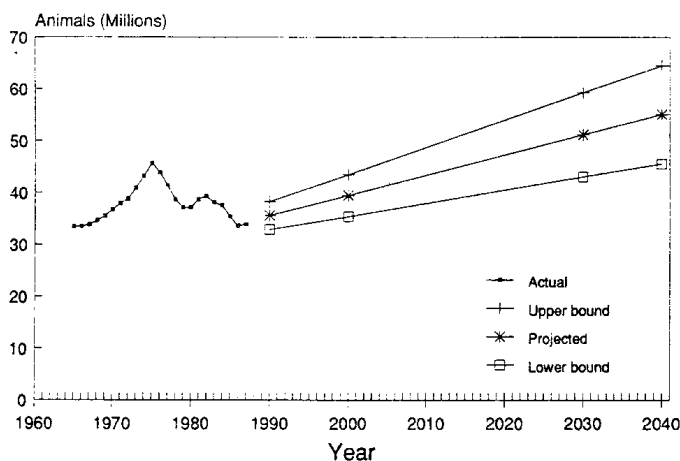
bound estimates (fig. 47). For this analysis, the projected inventory is used to determine the future forage demand from beef cattle.

Breeding ewe numbers were projected to be 18 million by 2040 or more than twice the 1985 inventory of 7.2 million (fig. 48). Although this projection is less than historical peaks (fig. 34), the decline in ewe numbers since 1965 would suggest that this projection is optimistic. The volatility of ewe numbers produces a wide upper and lower bound projection (fig. 48). Human population increases alone are insufficient to sustain a large increase in demand for lamb and mutton, and per capita consumption of lamb has declined (fig. 43). For this analysis, the lower bound will be used as the likely future for sheep inventory numbers and to determine the forage demand.

National Aggregate Forage Consumption Projections

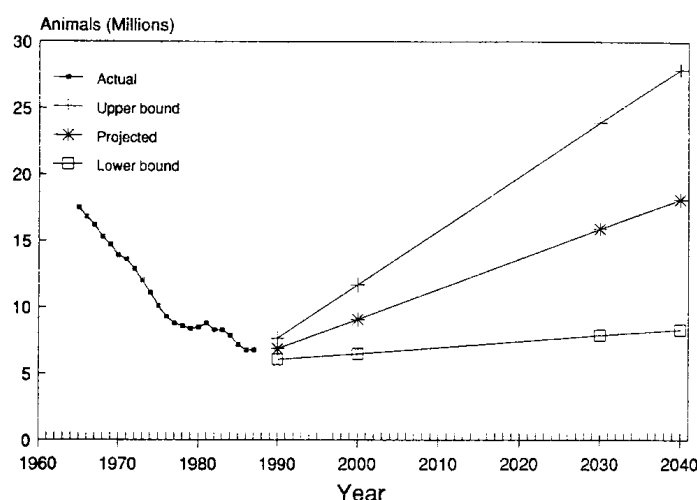
Aggregate grazed forage consumption was based on the above projected livestock numbers and an estimated per animal grazed forage demand from U.S. Department of Agriculture, Economic Research Service (ERS) budgets (Gee et al. 1986a, 1986b). Historical consumption of forage by beef cattle and sheep for 1980-87 and projections for 2000 through 2040 are shown in table 28. Upper and lower limits are based on the historical variability in livestock numbers (figs. 47 and 48). The upper and lower bounds of the forage demand projections for cattle differ from the mean (575.8 million AUMs) by 16%, whereas the upper and lower bounds for sheep forage demand are much greater at nearly 50% of the mean (35.5 million AUMs). This variability in livestock forage demand is a reflection of the decline in sheep numbers in 1965-85 and the variability in cattle numbers through two cattle cycles (fig. 34).

For this assessment, the projected future demand for forage by livestock is the sum of the projected demand



Source: Gee and Madsen (1988)

Figure 47.—January beef cow inventories (1965-87) and projection to 2040.



Source: Gee and Madsen (1988)

Figure 48.—January breeding ewe inventories (1965-87) and projections to 2040.

for cattle and the lower bound for sheep (total in table 28, fig. 49). These projected values reflect a slowly increasing demand for forage, driven by human population growth and, to a lesser degree, per capita consumption, exports, and imports. By 2040, total forage demand of 665 million AUMs represents an increase of 54% over the 1985 value for beef cattle and sheep (table 28). Based on this projection of demand, the forage supply would need to increase at least 1% annually.

These projections do not include other livestock, such as goats, horses, and hogs. The grazed forage demand for these livestock is small compared with beef cattle, and is assumed to remain small over the projection period. Wildlife projections are given in Flather and Hoekstra (in press) and the implications of this wildlife forage demand to range vegetation is discussed in Chapter 5 in the present report.

FORAGE SUPPLY

Supply projections for forage were based on the future availability of grazingland and the future technological improvements in forage production. The future land area needed for cropland and urban land are determined in the NIRAP model; the remaining land area is allocated to pasture, rangeland, and forest land based on historical trends. This land area projection for rangeland was then adjusted to account for the future implications of the Food Security Act. The likely future technological improvements were coupled with this land area projection to determine the future supply of forage.

Rangeland Area Projections

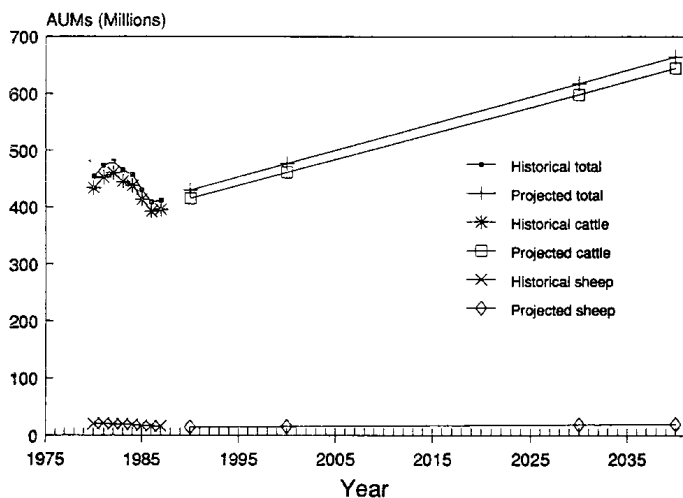
Projections made by the ERS indicate that pasture and rangeland area will increase slightly (1%) over the projection period (Miranowski 1988). The conversion of

Table 28.—Forage consumption for beef cattle and sheep (million AUMs) during 1980-87, and projections for 2000-40 in the United States.

Year	Beef Cattle			Sheep			Total
1980	434.0			20.4			454.4
1981	452.7			21.1			473.8
1982	460.9			19.9			480.8
1983	445.6			19.9			465.5
1984	438.5			19.0			457.5
1985	413.9			17.3			431.2
1986	392.8			16.3			409.1
1987	396.3			16.3			412.6
	Low	Projected	Upper	Low	Projected	Upper	Projected
2000	414.2	462.1	508.9	15.6	21.8	28.1	477.7
2030	504.3	599.0	693.8	19.0	38.2	57.4	618.0
2040	533.5	644.7	754.6	19.9	43.4	67.0	664.6

Source: Gee and Madsen (1988).

rangeland to cropland is assumed to be lower in the future than the extensive conversions of the 1970s. The future demand for cropland is assumed to be less because of reduced agricultural exports, increased growth efficiencies in feed grains, and increased feeding efficiencies in livestock. The increased production efficiencies will contribute to a decline in the acreage planted to feed grains and unplanted acres will return to a permanent cover of herbaceous vegetation. The decline in irrigated cropland, particularly in the West (Guldin in press, USDA Soil Conservation Service 1987c), also reduces the demand for conversion of rangeland to cropland in the future. These projections reflect the recent USDA Appraisal projections where future cropland used for crop production declines significantly (USDA Soil Conservation Service 1987c).



Source: Gee and Madsen (1988)

Figure 49.—Projected consumption of grazed forages by cattle and sheep, 1980-2040.

The ERS land area projections did not include any effect of the Food Security Act of 1985. The conservation provisions in this Act could potentially impact land use on cropland and rangeland. The "swampbuster" and "sodbuster" provisions of the 1985 Food Security Act are expected to slow the conversion of highly erodible rangeland to crop production. The conservation compliance provisions of the 1985 Food Security Act are also expected to reduce the conversion of highly erodible rangeland to cropland. The Conservation Reserve Program (CRP) will place nearly 45 million acres of cropland into permanent vegetation. About 85% of the acreage currently enrolled in the CRP has been planted to grasses (Dicks et al. 1988). At the end of this 10-year program, the vegetation cover on most of the western CRP lands will likely be native or introduced grass species. Over 65% of the grass plantings thus far have been tame (introduced) grass species. The CRP land planted to introduced grass species will probably remain in grass cover and be managed extensively. If fields seeded with grass species proceed through natural succession, range vegetation would be the likely vegetation type in the Rocky Mountain and Pacific Coast regions, and the states of Texas and Oklahoma in the Southern region. Because the future demand for cropland appears less than in the past, it is assumed that land placed in the CRP would not return to crop production.

In the western regions (Rocky Mountain, Pacific Coast, and the states of Texas and Oklahoma), it is assumed that by 2000, all CRP land will be managed as rangeland unless originally planted in trees. Western CRP lands planted to introduced grass are assumed to be managed as rangeland by 2000. From 2000 to 2040, this former set-aside land is assumed to remain in rangeland and be available for livestock grazing. In regions where forest is the climax and pasture is a viable economic alternative land use (Northern and Southern), the CRP land remains as pasture, unless originally planted into trees. At the national level, this land area projection represents a 5% increase in rangeland area from 1985 to 2040 (table 29).

The largest increases in rangeland area occur in the Rocky Mountain and Southern (Texas and Oklahoma) regions.

Increased Productivity from Technology

Productivity of rangeland was assumed to increase 0.7% per year during 1987-2040. Thus, by 2040, forage production per acre will have increased 47% over 1985 levels from the implementation of already developed technology.

Projections for Future Range Forage Production

Private Land

The supply of forage from private lands is the result of decisions made by individual enterprises. Those decisions rely on the availability and cost of land and technology. Based on the above projections for these inputs,

the supply of forage from private lands in 2040 is projected to increase by 52% over the 1985 levels.

Public Land

Projections for the amount of grazing to be supplied from National Forest System (NFS) lands, given the current and projected demand, were obtained from USDA Forest Service, Regional Offices 1-9 (1987, 1988). Overall, AUMs permitted to graze on NFS lands are projected to drop in 1990 and then gradually rise slightly over the 1986 level by 2040 (table 30). These increases are greatest in the California region (Region 5) at 17%. Declines are projected for the Southwest (Region 3) and the Southern region (Region 8) (table 30). The amount of grazing to be supplied from the Bureau of Land Management (BLM)-administered lands will likely be a continuation of the current levels (Peterson 1988). Grazing on NFS and BLM-administered lands dominates the public forage supplies and projections of supplies from other public lands, such as state or local, are assumed to remain at

Table 29.—Rangeland area projections (1,000 acres) by assessment region.

Year	Rocky Mountain	Pacific Coast	Southern	Northern	Total U.S.
1985	413,396	240,775	115,754	426	770,351
2000	440,227	240,810	127,531	340	808,907
2010	439,382	241,751	128,335	290	809,758
2020	438,367	242,388	128,950	249	809,953
2030	437,346	243,148	129,517	220	810,232
2040	436,356	243,643	130,024	196	810,219

Source: 1985, Bones (1989), projections based on Miranowski (1988) and the assumption that cropland placed in the Conservation Reserve Program would remain in permanent cover.

Table 30.—National Forest System historical records (1980-1986) and future projections (2000-2040) for livestock grazing (1,000 AUMs).

Year	National Forest System Region ¹								Total
	1	2	3	4	5	6	8	9	
1980	1,408	2,157	2,330	2,307	544	719	225	67	9,757
1981	1,394	2,166	2,370	2,316	529	724	231	69	9,799
1982	1,393	2,172	2,428	2,288	567	745	229	80	9,902
1983	1,391	2,190	2,531	2,311	596	741	234	78	10,072
1984	1,401	2,214	2,513	2,252	608	741	247	77	10,063
1985	1,400	2,170	2,504	2,357	621	745	248	78	10,124
1986	1,400	2,151	2,510	2,355	592	748	239	78	10,073
2000	1,401	2,199	2,100	2,300	620	779	200	78	9,677
2010	1,406	2,290	2,120 ²	2,300	625	777 ³	200	78	9,796
2020	1,411	2,315	2,160	2,300	630	774	205	78	9,873
2030	1,425	2,335	2,200	2,300	655	774	210	78	9,977
2040	1,440	2,360	2,240	2,300	725	774	210	78	10,127

¹Assessment Regions correspond to the following National Forest System region: Northern Rocky Mountain, 1, 2, 4; Southwest, 3, California, 5; Pacific North, 6; Northern, 9; Southern, 8.

²Interpolation between 2000 and 2040.

³Interpolation between 2000 and 2020.

Source: USDA Forest Service, Regional Offices 1-9 (1987, 1988).

current levels to 2040. The future supply of grazing from public lands will rise less than 1% by 2040.

SUPPLY/DEMAND COMPARISONS AT THE NATIONAL LEVEL

If forest and rangeland continue to contribute the same relative amount of forage to the total supply, then forage production on forest and rangelands will have to increase 54% by 2040 (fig. 50). This increase represents the demand on all sources of grazed forages (table 10). The area of rangeland is projected to increase by 5% by 2040 and the assumed technological increases in forage production result in a projected increase of 47% in forage supply. Thus forage supplies would appear to nearly meet the derived demand for forage (fig. 50).

The relatively flat projection for the supply of public grazing contrasts with the projected increase in forage demand (54%). Thus, in terms of total forage consumption, the relative contribution from public lands will decline. This projection implies that these additional forage demands, if met, will need to be supplied from the private sector. The amount of rangeland in the private sector is projected to increase by 5%. Much of this land will be former cropland where the productivity may be higher than the average for rangeland. Permanent plantings for the current set-aside programs, however, could have significant implications on the long-term supply of forage. In Oklahoma, native pasture produces only 50 pounds of beef per land unit whereas introduced pasture grasses produce 250 pounds of beef (Sims 1988a). Long-term maintenance costs of native versus tame pastures must also be considered. These forage differences will be critical in the determination of a land use offering the highest return on former CRP lands.

These supply/demand comparisons of forage are based on the demand for livestock production only and do not consider other range outputs that use forage, such as wildlife or wild horses and burros. A comparison of the future wildlife projections in western United States with these livestock projections is made in Chapter 5.

ALTERNATIVE SCENARIOS OF SUPPLY/DEMAND

Land Area Projections Based on Historical Trends

Historical forces affecting the use of rangeland have included: (1) demand for crop products; (2) withdrawal of land for recreational, wildlife, and environmental purposes; and (3) withdrawal of land for urban areas. Conversion of pasture and rangeland to other uses is not likely to increase dramatically in the future (O'Brien 1988). Future increases in crop productivity and declines in crop exports will result in a lower demand for cropland. The recent USDA Appraisal projects that cropland used for crop production will decline significantly in the future (USDA Soil Conservation Service 1987c). More than 350 million acres were in crop production in 1982, and by 2030, the Appraisal analysis suggests that only

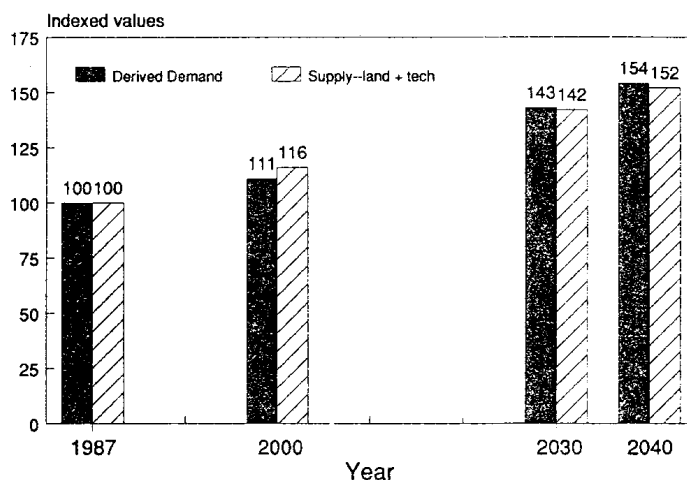


Figure 50.—Forage supply/demand projections indexed to 1987.

218 million acres will be needed to supply the crop production needs (USDA Soil Conservation Service 1987c). This analysis implies that potentially 152 million acres of cropland could sit idle, move into set-aside programs, or be converted to alternative land uses which bring a higher profit such as urban land.

The Appraisal projections were based on several assumptions concerning land use shifts (USDA Soil Conservation Service 1987c): (1) consumer demand for less meat and a leaner meat product will lower the demand for feed grains; (2) reduced exports place less demand for cropland; and (3) few conservation measures mitigate wind erosion, notably highest in the Great Plains. In the Appraisal analysis, cropland with the lowest profit per acre was identified as those acres which would be removed from crop production to reduce excess production and to meet the Conservation Compliance provisions in the Food Security Act of 1985. Sheet and rill erosion per acre is greater in regions other than the Great Plains, but attacking erosion by reducing acreage with the smallest profit margin per acre means that cropland comes out of production in areas such as the Great Plains. Less than 40% of the available cropland in the Great Plains is projected to be in production by the year 2000 (USDA Soil Conservation Service 1987c). Thus, the future uses of the projected idled cropland will depend on the alternative land uses available within each region.

Government crop-acreage control legislation has and will continue to have a significant impact on the use of rangelands. The long-term use of land in the most recent acreage-control program, the CRP, is uncertain. This land, if it remains in permanent vegetation cover, could increase forage supplies for wild and domestic herbivores. As assumed in the above land area projection, nearly 35 million acres from the CRP will remain in the grazingland base at the end of the program in 10 years. At the national level, the decline in pasture and rangeland area has been 0.33% per year over a period during

which cropland acres were in high demand (1969-1982).¹⁵ Over the next 10 years, the historical loss of pasture and rangeland would mean a loss of 23 million acres. Thus, if the CRP acres (over 35 million acres) remained in grass and shrub cover, the national total of pasture and rangeland area would remain relatively unchanged for at least two decades into the projection period.¹⁶ If rangeland area continued to be lost at the historical rate over the 1985-2040 projection period, and the CRP acres returned to cropland, the annual loss of rangeland would be 2.54 million acres and by 2040, the Nation's rangeland area would be 630 million acres, down from 770 million acres in 1985.

At the regional level, the current distribution of enrolled acres can be used to estimate the final distribution of CRP lands. The potential CRP enrollment acres in each region could be: Northern Rocky Mountain, 18.0 million; Southwest, 0.9 million; California, 0.3 million; Pacific North, 2.6 million; Northern, 8.8 million; and Southern, 12.4 million. If the historical annual losses of pasture and rangeland continued over the next 10 years, the following loss in total rangeland area by region would occur: Rocky Mountain (NR + SW), 12.0 million; Pacific Coast (PN + CA), 0.8 million; Northern, 9.2 million; and Southern, 1.5 million. Thus, in all Assessment regions, more land would be converted into permanent vegetation cover from CRP than would be removed from pasture and rangeland use over the same period. If the rapid land conversions of 1969-75 reoccurred, however, pasture and rangeland area in the Northern and Southern regions would decline. Historical data on regional conversions of forest grazing were unavailable.

Previous government set-aside programs have resulted in little acreage remaining in permanent cover. During periods of high crop prices that followed the set-aside programs, acres were plowed up and put back into crop production (Bartlett and Trock 1987). It is difficult to determine the future consequences of the entire Food Security Act of 1985.

Shifts in the Regional Supply of Forage

Regional forage consumption patterns differ across the United States. Forage from deeded non-irrigated land is the mainstay of livestock operations in the Southern and Northern regions whereas forage from a variety of sources is important in the western United States (table 18). The

¹⁵Frey and Hexem (1985) reported 890 million acres in 1969 and 820 million acres in 1982 of grazingland—forest, pasture and range. This 70 million acre loss represents an annual loss of 0.6%, or 5.3 million acres. When only pasture and rangeland acres are examined, 692 million in 1969 and 662 million in 1982, the annual loss is 0.33% or 2.3 million acres per year.

¹⁶When the declines in forest grazing are included with pasture and rangeland, the annual decline in grazingland area is 5.3 million acres, and over 10 years, this represents a decline of 53 million acres in the grazingland base. Forest grazing, however, has declined for a number of reasons, including changing management practices which exclude livestock grazing. Thus, although the CRP land will return acres to forest land, changes in management on forest land could impact forest grazing much more significantly.

future supply of forage from public lands will affect the forage demand differently across the regions.

If the relative distribution of different forage types were to remain the same as the distribution in 1985 (table 18), all feed sources would need to expand by 40% or more to meet the projected demand in 2040 (table 31). Beef cow inventories at the historical peak in 1975 were 29% greater than the 1985 inventories, suggesting that the forage base has the ability to expand to meet a 29% increase in demand. Crop residues are currently in surplus, and economic incentives could overcome the management problems associated with the efficient use of this feed type (Gee and Madsen 1988). Expansion of irrigated pasture seems unlikely, because of rising costs of water and increased demand for water by urban areas. The historical trends in permitted grazing on public lands suggests slight or steady declines in grazing. These possible shifts in terms of the distribution of forage sources, if the expected demand is to be met, will differ by region.

Shifts in the regional supply of forage were analyzed with the following assumptions about the future distribution of forage: (1) a decline in grazed forage from public lands (NFS and BLM), based on trends during the last 10 to 15 years¹⁷ (Gee and Madsen 1988); (2) irrigated grazing not expanding beyond 1985 levels; and (3) grazing of crop residues not expanding beyond 1985 levels. Assumption 2 reflects the premise that further expansion of irrigated pasture would be at the expense of more profitable cash crops, and the future costs of producing irrigated pasture will probably rise in relation to increasing water costs. Because water supplies are increasingly being sought by urban areas in the arid west, irrigation water supplies will continue to decrease, and shift agricultural water to only the most profitable crops. Assumption 3 is based on the premise that although many acres of crop residue go unused annually, the location and lack of fencing and water raise practical concerns in using this source of feed (Gee and Madsen 1988).

Under these assumptions, several feed sources decline in their relative contribution to the total forage, placing a greater demand for forage from deeded pastures (table 31). By 2040, irrigated grazing and crop residue are supplying the same amount of forage as in 1985 and public grazing has declined to 34% of the 1985 level. Total forage demand has increased 54% over the 1985 levels. Thus, the contribution that deeded nonirrigated forage must make to the total forage supply would have to increase by 71% over the 1985 contribution to meet these expected demands.

SUMMARY

Projections presented in this chapter suggest that the supply of forages at the national level will nearly

¹⁷Gee and Madsen (1988) reported that the decline in BLM grazing was nearly 5% per year during 1965-85 and was less than 0.2% on NFS lands at the national level. These are based on historical trends, not planning projections.

Table 31.—Projected consumption of grazed forage (million AUMs) by type of forage, 2040, by assessment region in the United States.

Type of forage	NR	SW	CA	PN	SO	NO	Total
Continuation of historical trends ¹							
Deeded grazing land							
Nonirrigated	157.8	10.3	33.4	31.2	280.0	72.4	585.1
Irrigated	6.7	0.2	4.7	6.7	1.2	—	19.5
Public grazing land	25.5	5.4	3.1	3.2	11.0	—	48.2
Crop residue	13.5	0.3	2.7	2.2	11.5	5.1	35.3
Total	203.5	16.2	43.9	43.3	303.7	77.5	688.1
Reduced forage substitutes ²							
Deeded grazing land							
Nonirrigated	181.8	12.3	40.1	39.9	290.7	72.6	637.4
Irrigated	4.2	0.2	1.9	2.2	0.8	—	9.3
Public grazing land	9.2	3.4	0.8	0.5	5.2	—	19.1
Crop residue	8.3	0.3	1.1	0.7	7.0	4.9	22.3
Total	203.5	16.2	43.9	43.3	303.7	77.5	688.1

¹Both analyses reflect the median projection for sheep and cattle.

²Projections based on the following assumptions: (1) Deeded nonirrigated rangeland is assumed to compensate for reductions in forage from different sources. (2) Supplies of public grazing land by 2030 are expected to drop an average of 82% below 1985 levels. This is based on projection of historical trends in AUMs for 1977-85 for FS and 1970-86 for BLM grazing. (3) It is assumed that there is no expansion in irrigated pasture production above 1985 levels. (4) It is assumed that crop residue consumption will stay at 1985 levels.

Source: Gee and Madsen (1988).

meet the demand for grazed forages in 2040 if certain assumptions are met. The most critical of these assumptions is the continued increases in forage production on forest and rangelands, resulting from implementation of existing technology. Recent analyses of range improvement practices, as discussed in Chapter 3, suggest that an improved livestock market will be necessary for the assumed application of this technology to occur. A critical assumption on the demand side is the constant per capita consumption for beef, veal, lamb, and mutton. A decline in per capita demand will, consequently, cause a decline in the demand for grazed forages. In addition, a shift in preference for leaner meat may cause a shift in the relative contributions of feed in the livestock production process. As discussed in Chapter 3, this feed shift may increase forage demand.

Projections at the regional level suggest that shifts in the relative contribution of forages will occur. Most notably is the decline of the relative contribution of public grazing. This decline will necessitate increased forage production on private lands if the projected forage demand is to be met. Projections of increased rangeland in the private sector could contribute to an increased supply, but forage production must also increase on a per acre basis to meet this derived demand.

The subtle relations between land available for forage production, production factors within regions, and shifts in livestock productions between regions were not analyzed in this assessment. This analysis assumes that cropland conversions similar to the late 1970s will not result in a resurgence of "sodbusting." Nor is it assumed that urbanization will dramatically affect the national supply of rangeland.

CHAPTER 5: SOCIAL, ECONOMIC, AND ENVIRONMENTAL IMPLICATIONS OF SUPPLY/DEMAND COMPARISONS OF FORAGE

INTRODUCTION

Projections made in Chapter 4 imply certain social, economic, and environmental conditions in the future. The desirability of this future depends on society's values concerning the range resource. These values encompass social, economic, and environmental concerns of individuals and groups. As future changes in society's values cannot be foreseen, this discussion of the implications of the projections will necessarily be based on the values that society historically has held and currently holds for the use of rangelands. These historical and current trends will be used to project probable future trends in the values society assigns to the uses of rangeland. This examination of the likely future social, economic, and environmental conditions sets the stage for describing the obstacles and opportunities to managing rangelands (Chapter 6).

SOCIAL IMPLICATIONS

Social Implications Defined

Held values, ideas held by an individual about something, regulate preferences that function to assign relative value to objects (Brown and Manfredi 1987). Society's held values about the range resource can be categorized into cultural, societal, psychological, and physiological subcategories. Cultural values are ideas and thoughts that make up a culture (Brown and Manfredi 1987) and might be exemplified with respect to the range resource in the value of the livestock business as a way of life in the western United States (Bartlett 1986, Pope 1987). Societal values are defined in terms of social relationships among people. The community focus and the social dependence among western ranchers described by Erlich (1985) are examples of societal values. Psychological values are related to the benefits that an individual perceives from the object of value (Brown and Manfredi 1987). Springtime hikes to see alpine flowers, birding trips to the grasslands, or knowing that bison or wild horses exist or that endangered plants have protected habitat reflect psychological values. And finally, physiological values may be associated with the range resource when interaction with the range resource through either work or recreation enhances health. Individuals might value the exercise associated with recreational hiking or horseback riding because of the health benefits, stress reduction, or a change of pace. The physical labor associated with operating a livestock enterprise might be valued because of

its physiological benefits. Although the social value of range vegetation has not explicitly been determined, this value does influence the behavior of those who might use the land (Pope et al. 1984b). Society's ideas about the range resource regulate preferences that function to influence the use of rangeland.

Social Implications of Projections

The projected futures for range, wildlife, water, timber, and recreation imply increased demand for these resources and an increased use of forest and rangelands (Chapter 4 this assessment, Cordell in press, Flather and Hoekstra in press, Haynes in press). The public's increasing interest in water quality will focus attention on the management of rangeland (Guldin in press). The social benefits of the range resource may be jeopardized with increased use and intensification of use unless proper management is implemented.

Livestock enterprises and livestock grazing on rangelands will continue to contribute to the social well-being of rural communities. The future intensification of rangeland use will change ranching as a way of life. The increased need to maintain viable ranching operations by marketing additional products, such as different meat products, wildlife, or recreational opportunities, will increase the interaction between ranching operations and urban dwellers. More opportunities will likely exist for urban dwellers to experience the range resource. Cordell et al. (1983) projected that the demand for primitive, semi-primitive, and roaded natural and rural areas will outstrip future population growth. The value of wilderness or habitat for threatened and endangered species within a functioning ecosystem has increased with the passage of legislation such as the Wild Free-Roaming Horse and Burro Act of 1971, and the Endangered Species Act of 1973. This value is often held by people who may never experience the resource directly.

Social values influence the allocation of forage to wildlife, wild horses and burros, and livestock. Many different views exist concerning the use of rangelands by grazing animals. The extremes might be characterized by those who feel that all resource damage is linked to livestock grazing, and those who feel that rangelands should be managed for a single use, livestock grazing. Pressure exists to remove livestock from public lands. Recent concerns about chemicals in the environment have shifted the emphasis in vegetation management to biological control methods. The role that livestock have in vegetation management will be difficult to determine in an atmosphere demanding livestock removal from

public lands. The perception that rangeland health has deteriorated primarily from livestock grazing will be heightened in a future where demand for more wildlife habitat, wild horses and burro habitat, and threatened and endangered plant and animal species are cast up against increased livestock production on forest and rangelands.

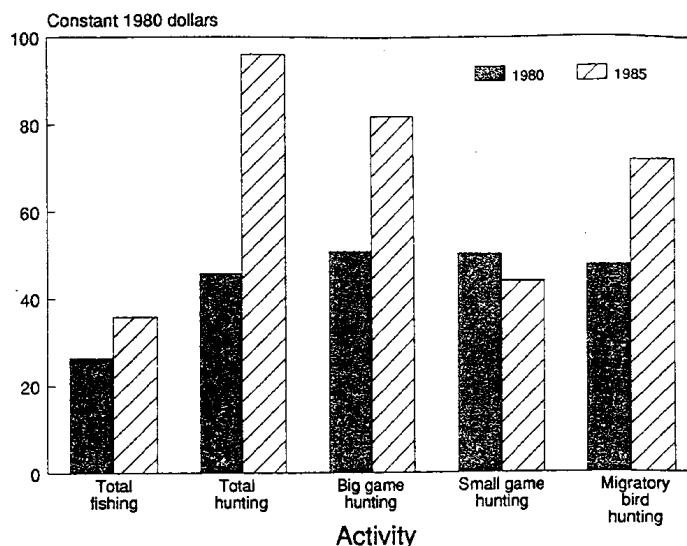
ECONOMIC IMPLICATIONS

Economic Implications Defined

Economic implications are a special case of social implications and concern the monetary aspects of range forage production. Because it is difficult to assess the value of vegetation to uses such as wild horses and burros, or threatened and endangered species (Bartlett 1986), economic implications traditionally have been limited to a valuation of range forage for livestock. Forage for domestic grazing is valued on the site and at the margin (Bartlett 1986) and will vary with different enterprise structures. To provide sufficient information to compare other uses of forage, an understanding of the joint production of different animal species using the same resource base is necessary but little progress has been made toward this understanding. This situation is complicated further by uses such as the harvesting of native plants, so the plant, not an animal, is the product. Ultimately the monetary valuation of range vegetation to produce this diverse mix of outputs must be determined to examine resource tradeoffs. In the past, most of these uses were marginal, that is, did not determine the use of large areas of rangeland. In a future demanding more outputs from forest and rangelands, the economic valuation of different uses may determine rangeland use.

Economic Implications of Wildlife Use

The amount spent per hunter or fishermen for access to private lands has increased substantially since 1980 (fig. 51). On an annual basis, these increases vary from 7% for fishing to 12% for big game hunting. Access fees are a function of several factors including interpersonal relationships between the parties buying and selling the lease, the availability of game, services and facilities, and the general hunting experience. Although these factors make it difficult to precisely determine the value of wildlife, Pope and Stoll (1985) concluded in their study of Texas hunting access fees that the provision of services and facilities generally does not enhance the value of the hunting experience as much as access to a variety of game species on an adequately large parcel of land. Thus, this rise in access fees is an indication of an increase in the value of grazing in wildlife production. Although many success stories can be told on Texas rangeland, the viability of enterprises based on wildlife alone is still being explored. Unless future possibilities for economic returns from wildlife grazing increase, the



Source: Flather and Hoekstra [In press]

Figure 51.—Trend in private access fees (dollars per spender) for fishing and hunting, 1980, 1985.

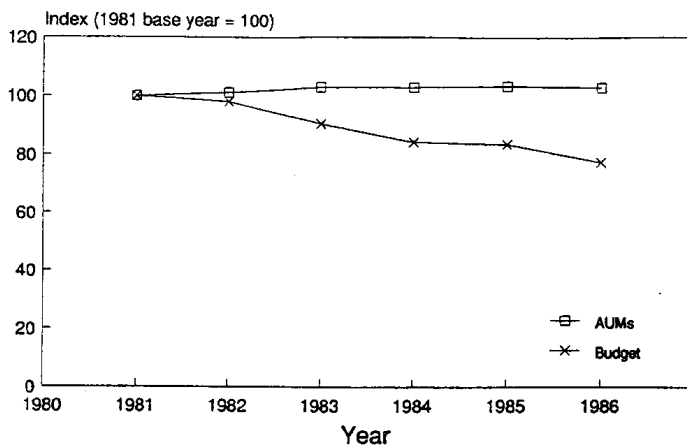
projected scenario implies a grazingland capable of supplying forage to livestock.

Economic Implications of Livestock Use

Improved range productivity, increased animal feeding efficiencies, and an increasing rangeland base contribute to an improved livestock industry in the future. Grazed forages remain at 80% to 90% of the total feed mix for livestock and it is unlikely that this relatively inexpensive source of feed will decline in the total feed mix in the future. Grazed forage is currently the cheapest source of feed and will likely remain inexpensive relative to other sources of feed. With the rangeland base increasing only 5% nationally, the projected forage supply relies on the implementation of currently available technology to meet the future demand for forage.

The distribution of sources for grazed forages will likely vary from historical patterns. Projections for Bureau of Land Management (BLM) permitted AUMs indicate a flat future supply, and projections for National Forest System (NFS) lands indicate a rise of less than 1% in permitted grazing (Chapter 4). The 1987 budget, in terms of constant dollars, for the NFS range management program has declined 22% since 1981. The number of AUMs authorized on NFS lands has remained nearly constant at around 10 million AUMs (fig. 52). The administration of these permits is only one responsibility of the range management program of NFS (USDA Forest Service 1987d).

Projected declines in irrigated lands will also impact the amount of pasture irrigated (Guldin in press, USDA Soil Conservation Service 1987c). The average area per grazing animal in western United States is lower than other parts of the United States (table 21) only because



NOTE.—Budget reported in constant 1981 dollars and is the net of inflation or deflation.

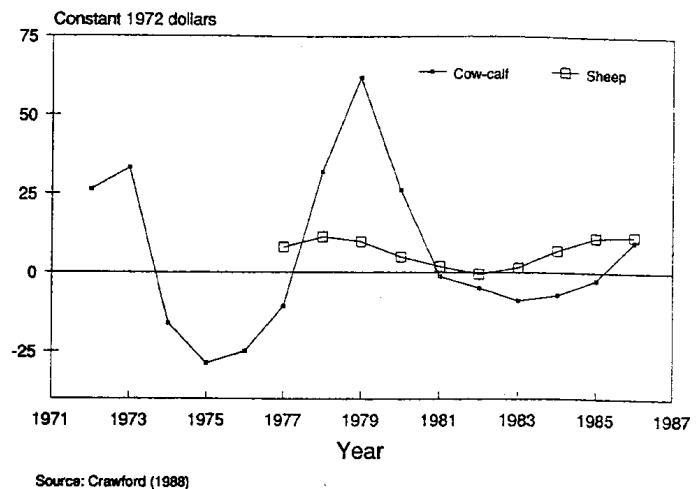
Source: Comanor (1988b)

Figure 52.—National Forest System range annual budget and authorized grazing use, 1981-1986.

of the high productivity of irrigated pasture and the accessibility of public grazing. Increasing costs of irrigating and the flat projected supply of federal grazing will result in herd reductions on those enterprises unable to implement necessary technology to improve forage production on their remaining land.

With the overall increase in forage demand, the decline in the relative share of public grazing and irrigated pasture implies that private lands will need to make up the difference in forage supply. Livestock operations unable to buy, grow, or otherwise obtain private forage for all seasons to replace public forage will not be part of the future growth in this industry. Thus, fewer livestock operations will be associated with public lands, with a potential decline in service industries associated with livestock production in these rural communities. This decline, however, is tied to social pressure to remove livestock from public lands, which is related to an increased demand for recreation and wildlife outputs. Services associated with recreation will likely increase in these rural communities.

At the state level, the future significance of this relative decline in federal forage can be seen in comparisons of the contribution that federal forage makes to the total feed mix within a livestock enterprise. Across the 13 western states, the median dependency level on federal forage is 23% (USDA Forest Service and USDI Bureau of Land Management 1986). In the southwestern states where animals can graze yearlong on federal lands, enterprises may get 36% (Nevada) to 44% (New Mexico) to 60% (Arizona) of their total feed from federal grazing. The northern Great Plains states depend on federal forage to supply from 11% (Montana) to 13% (Nebraska) of the total feed (USDA Forest Service and USDI Bureau of Land Management 1986). Amounts for other western states fall in between these examples. Even for livestock



Source: Crawford (1988)

Figure 53.—Net returns on sheep and cow-calf operations: receipts less cash costs for 1972-1986.

enterprises relying on federal forage for only 11% of the total feed mix, this amount may be difficult to replace as most of the enterprises utilizing federal forage would be in counties where most of the land would be managed by the federal government.

The recent volatility in beef cattle markets has spurred new approaches to diversifying a livestock operation (Heimlich and Langer 1988). Since 1975, livestock numbers have declined as the inventory adjusted to the relatively constant per capita demand for meat. The recent agricultural credit crisis has placed considerable stress on the livestock industry (Drabenstott and Duncan 1982). An estimate of the profitability of the beef cattle and sheep enterprises can be seen in cash receipts minus cash costs¹⁸ (fig. 53). Profit volatility was very high for cow-calf operations in 1972-85. A profit has been made more often in sheep operations than in beef cattle since 1977 (fig. 53). Net cash returns for cattle operations were negative during 1981-84 when feed costs were high and cash receipts were low (Bowe 1987). When capital replacement costs are added into this equation, cattle operations were profitable only during 1978-80 over the entire 1977-86 period. In the past, cash shortfalls may have been weathered through rising land values or mineral income, but recent declines in land and mineral prices have resulted in financial losses to ranch operations (Bowe 1987).

Cash shortfalls imply an inability to sustain the necessary long-term improvement needed in a livestock operation. Recent indications show that range improvements have not been and are not being put in place (Gilliam 1984, Lewis and Engle 1982). The projected supply scenario from Chapter 4 assumes an annual increase in forage productivity of only 0.7%. The historical volatility in livestock production costs will affect the ability of ranch/farm operators to implement technology necessary

¹⁸Source: Terry Crawford, unpublished data obtained from the USDA Economic Research Service cost of production survey.

for long-term improvements in forage production. In the past, a diversity of incomes from rangeland was important to maintain cash flow and long-term improvements. The imperative to be efficient and to diversify in order to remain in the industry was seen in the early 1980s (Special Advisory Committee 1982) and this appraisal is likely to reflect successful management strategies for the future as well.

Recent diversifications in ranching have included bed and breakfast operations (Wyoming Farm Bureau 1987), recreational opportunities such as cross-country skiing (Freese and Coble 1988) and hunter lease agreements (White 1987); harvesting the seed or the plants of native species (Goodin and Northington 1985, Proulx 1984), tree nuts, wood chips or fuelwood; alternative meat products such as buffalo, and livestock products emphasizing nutritional quality or production without chemicals (Briney 1987, Cohn 1987, Zuckerman 1987). The economic value of the range resource will reflect these outputs. Although less than 1% of private grazing land is currently used primarily for wildlife or recreational activities (Heimlich and Langer 1988), land owners who charge access fees for recreation or hunting are more likely to implement range improvement practices (Lacey et al. 1988).

ENVIRONMENTAL IMPLICATIONS

Environmental Implications Defined

Environmental implications involve an assessment of the ability of the land to sustain long-term productivity of range vegetation. Capital, labor, and state-of-the-art technology influence the productive capacity of forest and rangelands.

Environmental Implications of the Projections

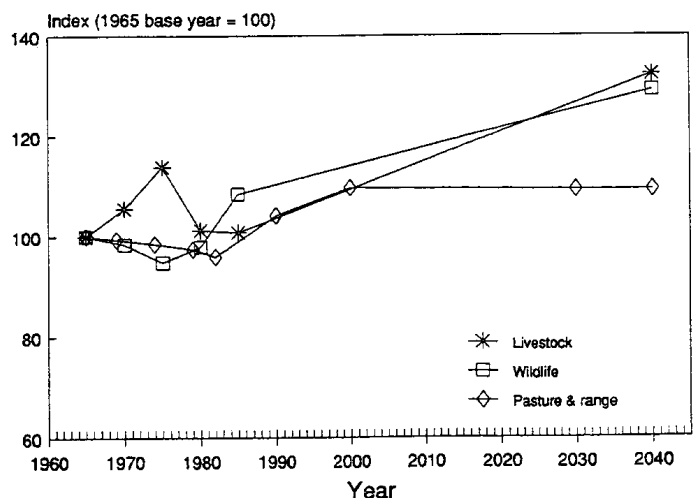
The demand for meat, and consequently forage, are projected to be great enough to foster the implementation of technologies to sustain and enhance range productivity. Analyses explicitly linking the environmental and production processes and income objectives for either forage production or livestock production at the national level have not been developed. Economic theory would suggest that a strong demand for a product would strengthen the market for that product. The future scenario assumes an improved livestock market, and the consequent implementation of additional technologies to improve forage production. This future demand implies that management on rangelands will intensify.

The national projections for the supply and demand of range forage for livestock considered the potential impact of land use changes but these projections were made in isolation of the future supply/demand of other outputs, such as timber or wildlife. Multiresource interactions were examined in the regional case study discussed in Chapter 2 and for NFS lands at the national level by Hof and Baltic (1988). Those scenarios indicated

an interaction between the production of timber, the production of forage, and to a greater degree, the production of wildlife.

Forest and rangeland supply food and habitat for both wildlife and livestock. A comparison of the projections for livestock grazing (from the present assessment) and wildlife grazing (from the Wildlife Assessment, Flather and Hoekstra in press) indicate a potential conflict (fig. 54). Big game numbers (elk, deer, and antelope) are projected to increase 19% by 2040 over 1985 inventories in the western United States. Livestock numbers are projected to increase 32% over the same period. Rangeland area is projected to increase only 5% by 2040 (fig. 54). The enhanced rangeland productivity is projected to meet only the increased forage demand for livestock. Even though domestic and wild grazers and browsers are often complementary users of rangeland and, thus, competition is not 100% temporally and spatially, grazing pressure from wildlife and livestock will increase in the future, beyond the projected supply. This intensive use of our Nation's ecosystems implies little likelihood that the condition of the vegetation or the productivity of the system will improve unless sufficient technology is implemented to enhance the productivity of these ecosystems.

Although enhancing rangeland productivity for livestock may increase the food and habitat for wildlife, some management intensifications for livestock may not necessarily improve the future wildlife situation. For example, the paddock cell layout associated with short duration grazing systems increases both human and domestic animal activity near the center of the cell where the water tank is often located. Some indications exist that wildlife avoid these highly congested areas, thus restricting wildlife access to water (Prasad and Guthery



NOTE.—12 of 15 western states reported.

Source: USDA (various years); Flather and Hoekstra [in press]

Figure 54.—Trends in livestock and wildlife AUMs and rangeland area in the western United States over historical (1965-1985) and projected periods (2000-2040).

1986). Even if the projected rising forage production were available to wildlife, this increase would not appear sufficient to meet demands from both domestic and wildlife grazing.

Obstacles and opportunities exist for allocating the grazing resource on rangelands. Economics and increasing regulation of agrochemicals have restricted the use of some improvement techniques. Previous overgrazing has left some range managers with degraded rangeland ecosystems. The U.S. Congress, Office of Technology Assessment (1981) reported that on some particularly fragile lands there are no currently available ways to sustain high levels of production. On other lands, technologies to enhance productivity are often not applied because users are not convinced the new technology will be profitable, innovative technologies require more management, and capital investment is greater than users can afford (U.S. Congress, Office of Technology Assessment 1981). The use of rangelands can be enhanced, however, with multiple species grazing (Baker and Jones 1985). These technological enhancements require the broadening of forage management and wildlife management into vegetation management.

DETERMINANTS OF VALUE

Range Forage For Livestock Production

The value of range forage grazed by livestock is derived from the value of the livestock produced. Thus, the value of range forage is a function of the values of the livestock, the value of other types of feeds and forage that might be used, and the efficiency of the livestock operation (Bartlett 1986). On NFS lands and BLM-administered lands, range forage is allocated by public policy. Thus, the value of range forage is not determined within a market system. In the past, the determinants of value within the fee system have included beef cattle prices, prices paid index, and the private grazing land lease rates (USDA Forest Service and USDI Bureau of Land Management 1986). A comparison of the 1987 public grazing fees and estimates of the market clearing price of forage by regions are shown in table 32.

An important consideration for resource decision-making is the current value of range grazing for livestock and any changes in that value in the future. The value of range forage over time should reflect changes in the factors that affect the use of range forage. These factors include outputs produced from forage, i.e., beef cattle or sheep, and changes in the production of other types of feeds that could be used as substitutes. Thus, trends in the value of private range forage might reflect historical trends in the available market transactions for forage, such as private grazingland lease rates. The valuation of private grazingland lease rates includes a multiplicity of factors, among which are services and facilities provided with the lease. As any historical shifts in these additional factors are difficult to examine, caution must be exercised in evaluating the trends in market prices associated with private land lease rates. In

Table 32.—Range forage prices (dollars per head per month) as determined by grazing fees on National Forest System lands and by market value appraisals.

National Forest System Region ¹	Grazing fee ²	Market clearing price ³
1	1.35	5.64
2	1.35	6.34
3	1.35	4.73
4	1.35	4.12
5	1.35	4.53
6	1.35	4.36
8	0.65	3.33
9	2.53	3.33

¹Assessment regions correspond to the following National Forest System regions: Northern Rocky Mountains, 1, 2, 4; Southwest, 3; California, 5; Pacific North, 6; Northern, 9; Southern, 8.

²See USDA Forest Service, and USDI Bureau of Land Management (1986), for grazing fee formula. Regions 8 and 9 prices were derived from equivalent hay price. Prices are based on dollars per head per month as used in grazing fee bills for collection.

³Market Value Appraisal, 1983, USDA Forest Service, updated to 1987. Regions 8-9 prices derived from hay prices.

Source: Frandsen (1988).

addition, the value of deeded private range may include values not measured in the private grazing land lease rates, such as the option to use the deeded land with greater flexibility than leased grazing land.

As the projection period for the assessment is 50 years, two historical series will be examined to assess trends in range forage values: the recent historical trend (1968-86) and the long-term historical trend (1870-1970). The trends in the recent historical past are most likely to influence the next 10 years whereas the longer historical series are most likely to influence the future long-term trend. The price in constant dollars (net of inflation) will be used to determine trends in the value of the range resource for livestock grazing.

The recent historical trends in the determinants associated with livestock grazing are given in table 33. The high inflation rates of the 1970s are seen in the difference between the nominal prices and the real (constant) prices. Although all nominal values increase over 1968-85, constant dollars remain nearly steady or decline for beef cattle, private grazing land lease rates, and wool prices. The cyclical nature of livestock production is also apparent in the cyclical pattern of the beef cattle prices.

The recent historical trends in the private grazing land lease rates (constant dollars) indicate a slight decline of 1% annually during 1966-86 (fig. 55). Private grazing land lease rates include various services other than the use of the range forage. This trend also reflects any changes in services other than forage provided, as well as a potential change in the value of the private grazing land lease rate.

Trends in hay prices (constant dollars) during 1968-85 have moved upward about 0.7% annually (fig. 56). Greater volatility is seen in this series when compared with the private grazing land lease rates (fig. 55).

Table 33.—Hay prices (dollars/ton), livestock prices (dollars/CWT), private grazing land lease rates (PGLLR) (dollars), and wool prices (cents/lb) from 1968 to 1986.

Year	Hay		Beef cattle		PGLLR		Wool ¹	
	Nominal	Real	Nominal	Real	Nominal	Real	Nominal	Real
1968	23.60	23.60	22.04	22.04	3.65	3.65	40.5	40.5
1969	24.70	23.40	27.00	25.57	3.82	3.62	41.8	39.6
1970	26.10	23.42	29.50	26.48	4.05	3.64	35.4	31.8
1971	28.10	23.86	29.50	25.05	4.06	3.41	19.6	16.6
1972	31.30	25.38	36.80	29.84	4.17	3.38	35.0	28.4
1973	41.60	31.68	43.00	32.75	4.57	3.48	82.7	63.0
1974	50.90	35.54	39.20	27.37	5.82	4.00	59.2	41.3
1975	52.10	33.12	35.20	22.38	5.75	3.66	44.8	28.5
1976	60.20	38.97	36.10	21.57	6.37	3.81	66.0	39.4
1977	53.70	30.08	36.00	20.17	7.06	3.95	72.0	40.3
1978	49.80	26.00	47.60	24.85	7.11	3.71	74.5	38.9
1979	59.60	28.59	64.90	31.13	7.53	3.51	86.3	41.4
1980	70.90	31.19	64.20	28.24	7.88	3.47	88.1	38.8
1981	67.30	26.99	59.10	23.70	8.83	3.54	94.4	37.9
1982	69.30	26.13	57.70	21.75	8.36	3.15	68.6	25.9
1983	75.80	27.50	56.40	20.45	8.85	3.21	61.2	22.2
1984	72.70	25.45	57.79	20.19	8.86	3.10	79.5	27.8
1985	69.10 ²	23.43 ²	53.70	18.16	8.40	2.84	63.3 ²	21.5 ²
1986	NA	NA	51.79	17.05	8.50	2.80	NA	NA

¹Prices do not include wool support price payments.

²Preliminary.

Note: Real prices are reported in constant (1968) dollars and are net of inflation or deflation.

Source: Hay and wool, U.S. Department of Agriculture (1968-1985); beef cattle prices, PGLLR, USDA Forest Service, and USDI Bureau of Land Management (1986).

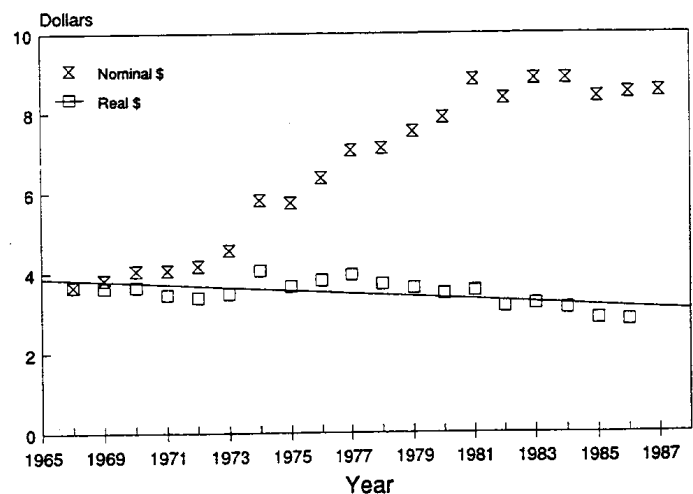
An examination of the determinants over a longer historical period indicates positive increases in all values, although fluctuation in prices associated with wool has been considerable (figs. 57 and 58). The annual increases in beef cattle prices and in sheep and lamb prices (constant dollars) over this 100 year period is nearly 1% (Manthy 1978). Wool, hay, and corn prices (constant dollars) show a greater fluctuation over this period but no clear trend is seen.

Range Vegetation

The determinants discussed above relate to the value of range forage in livestock production. The value of range vegetation is reflected in, but is not often measured by the value of grazing for wildlife, wild horses and burros, the habitat for threatened and endangered species, and the recreational experiences. The future value of range vegetation based on other output indicators might be different from the trends determined from forage for livestock. Increases associated with access hunting fees may reflect an attempt by the producer to find the market equilibrium price, but over the short-term indicate a substantial increase in value (fig. 51). Although not expressed in terms of monetary value, the increased number of threatened and endangered plant species suggest an increase in the value of rangelands as habitat for these species. As discussed earlier in this chapter, increased competition for the mix of resource outputs imply a continued and increasing social value for range vegetation management.

SUMMARY

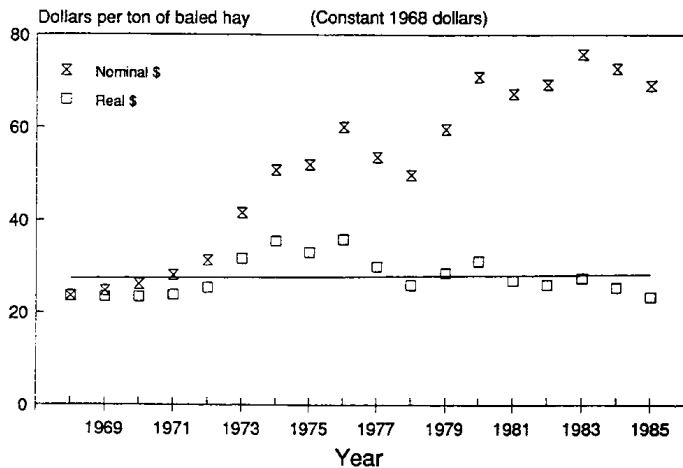
The desirability of the projected future depends on society's social, economic, and environmental values concerning the range resource. Society's ideas about the range resource regulate preferences that function to influence the use of rangeland. Livestock enterprises and livestock grazing on rangeland will continue to contribute to the social well-being of rural communities. The increased demand for recreational experiences will



NOTE.—Real rates are reported in constant 1968 dollars.

Source: USDI, Forest Service and USDI, Bureau of Land Management (1986)

Figure 55.—Private grazing land lease rate.



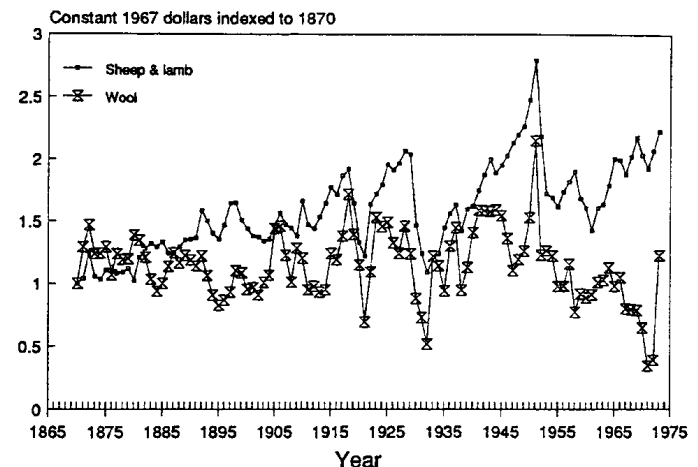
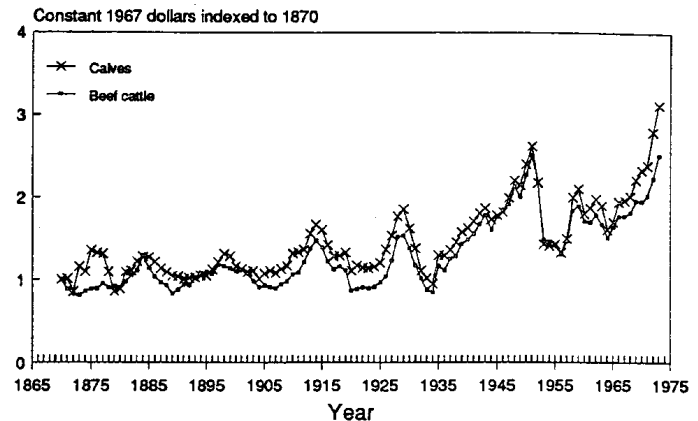
Source: USDA (various years)

Figure 56.—Hay price per ton received by farmers, 1968-1985.

increase the interaction between ranching operations and urban dwellers. Concern for rangeland health will be heightened in the future as demands for wildlife habitat, wild horse and burro habitat, and habitat for threatened and endangered plants and animals are increasing along with livestock production on forest and rangelands.

Although the projected supply of forage appears adequate to meet the projected demand for livestock grazing, the distribution of grazed forages will likely vary from historical patterns. In light of the overall increase in forage demand, a decline in relative shares of public grazing and irrigated pasture suggests that livestock operations unable to buy, grow, or otherwise obtain forage for all seasons to replace public forage or irrigated pasture will not be part of the future growth in this industry. Thus, fewer livestock operations will be associated with public lands, with a potential decline in service industries associated with livestock production in these rural communities. This decline, however, is tied to social pressure to remove livestock from public lands, which is related to an increased demand for recreation and wildlife outputs. Services associated with recreation will likely increase in these rural communities.

The enhanced rangeland productivity is projected to meet only the increased forage demand for livestock. Although domestic and wild grazers and browsers are often

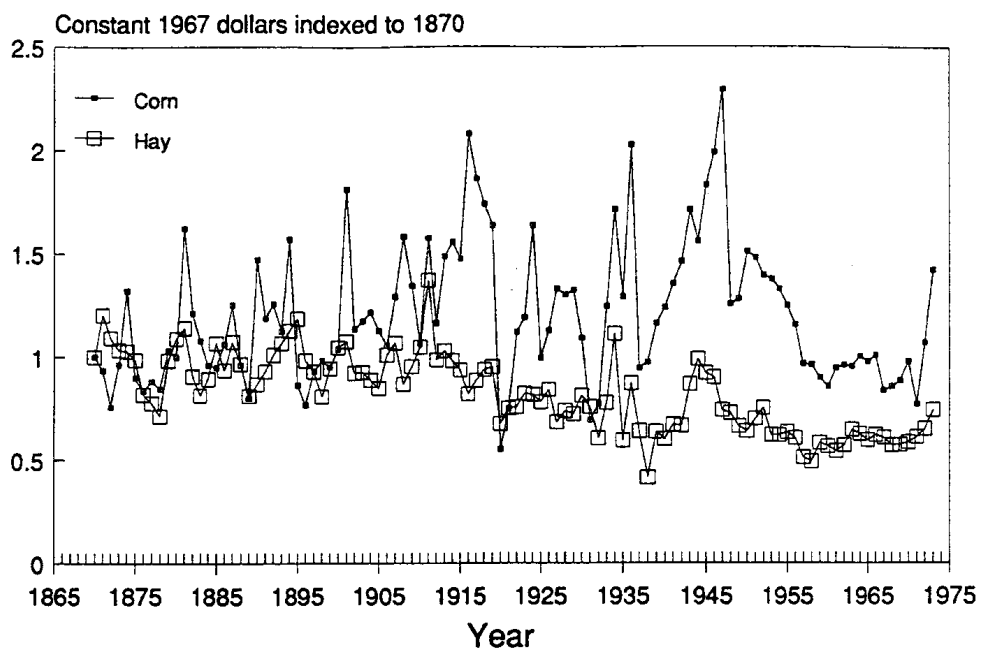


Source: Manthy (1978)

Figure 57.—A 100-year historical trend of prices received: livestock and wool.

complementary users of rangeland and, thus, competition is not 100% temporally and spatially, grazing pressure from wildlife and livestock will increase in the future.

Recent historical trends in the values of private grazing land lease rates, prices for beef cattle and wool indicate a flat or declining trend. Trends over the period corresponding to the projection period of the assessment (50 years) indicate an increase of 1% in the prices of beef cattle, sheep and lamb. Wool, hay, and corn prices show a greater fluctuation over this period with no clear trend.



Source: Manthy (1978)

Figure 58.—A 100-year historical trend of prices received for corn and hay – indexed to 1870.